Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 213 MAY, 1932 No. 5

THE DESIGN, MATERIALS AND ERECTION OF THE KILL VAN KULL (BAYONNE) ARCH.*

BY

LEON S. MOISSEIFF, C. E., MEM. AM. SOC. C. E.

Advisory Engineer of Design, Port of New York Authority.

From time immemorial, from the dusk of prehistoric tradition transmitted from tribe to town, the bridging of rivers has been surrounded with a mystic veil. From the medicine man to the priest and from the priest to the engineer, the pontifex, the bridge builder carries with him something of the knight who slays the dragon. The building of a permanent path over the rushing stream is believed by the people to be an invasion of the domain of the river gods. The river resents the work of man and frequently destroys the bridge and demands human life. One finds in the lands of Europe widely spread the legend of sacrificial rites in which pure virgins or innocent children were immured alive in the masonry of the bridge to appease the river deity and his mischievous host. The speaker himself has heard many a time in the City of New York the legend, which at one time seemed to have enjoyed much popularity in the public imagination, that the engineer of the Brooklyn Bridge paid with his life for his bold undertaking. And thus something of the heroic has adhered to bridge building in the popular mind. But

* Presented at a meeting held Thursday, December 12, 1931.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

also something of the priestly has attached itself to the engineer in his service: directly he serves the needs of the community and assumes responsibility for many lives.

While training and technical routine have removed from the engineer much of the awe inherent in the first steps of any creative act, the importance of a major problem vividly brings before him the natural forces he has to combat. Incessantly, the forces of nature are lurking and espying a slip, a mistake, a neglect the engineer may make to destroy his work. At such times the engineer takes an account of himself and of his knowledge. Like the high priest of yore, he purges his soul to be worthy of his undertaking; and humbly he begins his work.

LEGISLATION AND AUTHORIZATION.

The planning, designing and erecting of a bridge over the Kill van Kull presented to the engineers a major task in bridge building both by the length of span involved and by the outlay in funds required. Staten Island is politically one one of the boroughs of the City of New York, known as the Borough of Richmond. It is divided from the State of New Jersey by a navigable water. Its northern shore is separated from the southern shore of the Bayonne peninsula by an estuary about a quarter of a mile wide and two miles long known by its Dutch name, the Kill van Kull. In 1925 and 1926 the legislatures of the States of New York and New Jersey authorized the Port of New York Authority, a public body created by an agreement between the two states and approved by Congress, to construct, operate and maintain a bridge over the Kill van Kull. The engineers of the Port of New York Authority began work on surveys of the land and the traffic, made borings along the lines of the probable locations and entered upon intensive studies of comparative designs and estimates based on them. A tentative report of the findings was submitted by the Port Authority to the State Legislatures. This report stated that a bridge for vehicular traffic was justified, that it was financially feasible and that it could be constructed for sixteen million dollars within four years. The two states then authorized and ordered the Port Authority to proceed with the building of the bridge.

Location of Bridge.

The location of the bridge was carefully studied and much consideration was given to existing streets and property affected. Four alternate locations were selected for special study. The more convenient highway connections and the more economical approaches determined the choice of the adopted location. Much consideration was given to the fact that the bridge as built makes an angle of about 60 degrees with the U. S. Pier Head Line and requires a considerably greater span at a higher cost than one at right angles. The distance between pier head lines measured along the axis of the bridge is about 1,386 ft. Navigation requires that the distance between pier lines should be kept clear and the masonry piers had, therefore, to be placed wholly within these lines. The width of the bridge piers and the fact that they are built normally to the axis of the bridge thus add to the length of the span required. For the adopted location the least span feasible thus became 1,500 ft.

Navigation Clearances.

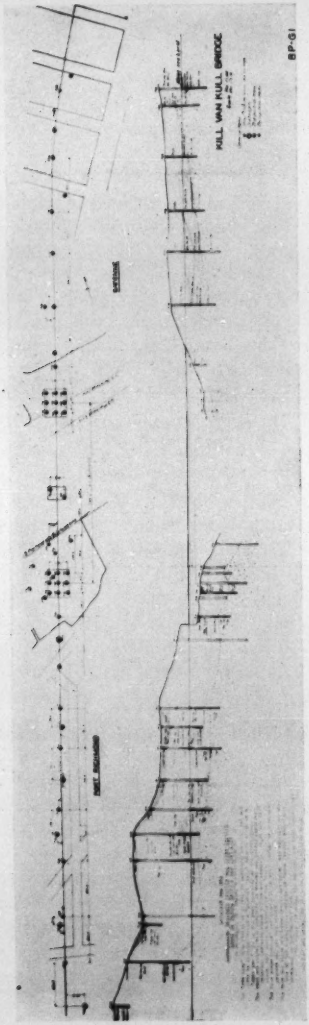
The Kill van Kull is an important shipping artery. Its tonnage exceeds that of the Suez Canal. It was, therefore, clear from the start that noninterference with shipping demands ample width and height of opening under the bridge.

The War Department ultimately approved a plan for an arch with a clear width between pier head lines and a vertical clearance of 150′ above mean high water at mid-span reducing to not less than 135 ft. for a channel 1,000 ft. wide.

Borings and Cores.

The geological conditions of the site offered on both shores excellent foundation. Geologically Staten Island is a part of the mainland and a continuation of the Jersey palisades. Solid rock extends from Bayonne across the Kill van Kull to Port Richmond on Staten Island. Borings were made along the line of the proposed location. They are shown on Fig. 1. Long solid cores of traprock were recovered from the bore holes and there was no loss of core length, indicating a continuous ledge of rock. Compression tests were made on core specimens from the borings on cylinders 1 3/8 in. diameter and a height of 2 to 1, and developed a breaking strength

FIG. 1.



of 37,000 to 40,000 lb. per sq. in. No initial cracks were noted and the fracture showed a very hard and tough structure without stratifications. This rock is encountered about 10 ft. below water on the Bayonne side and from 25 to 35 ft. below water on the Port Richmond side.

COMPARATIVE STUDY OF SUITABLE TYPES OF BRIDGE.

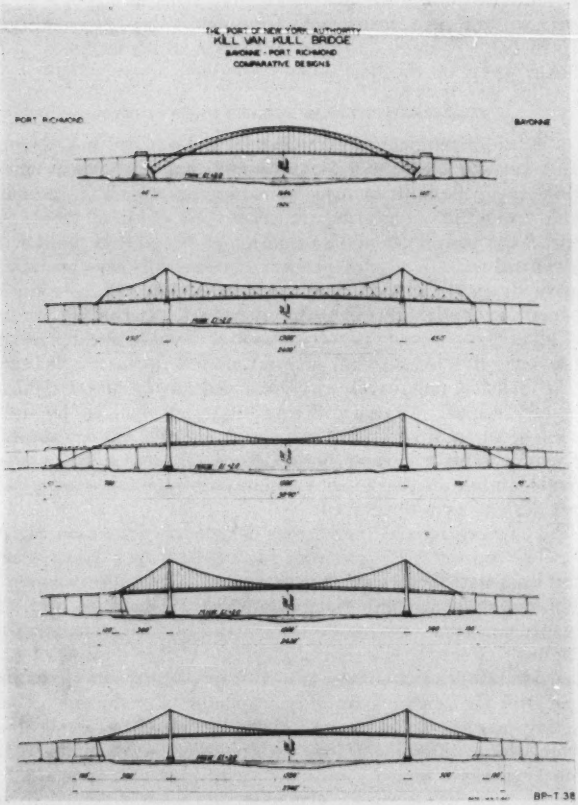
A bridge requiring a main span of 1,500 ft., with horizontal and vertical clearances of the magnitudes previously mentioned, can be built of three general types which all are suitable from the engineering and economic point of view. Of these, the cantilever and suspension type could be built with a central span of 1,500 ft. center to center of piers, while the arch to provide the same clearances required a span of nearly 1,700 ft. between the skewback bearings. Studies of all of these three types were made. They were all based on the same live loads, wind pressure and temperature changes. The identical unit stresses were allowed for the materials used in all designs. Where different materials had to be used, equivalent and proportioned unit stresses were applied. Fairly complete designs of bridges of the three types were made, and in the case of the suspension bridge three independent designs were developed.

The elevations of the various designs are shown on Fig. 2.

The cantilever design proved to be the most expensive and the least satisfactory in appearance. It therefore was early eliminated from further consideration. The arch and the suspension type were made the subject of further exhaustive engineering and architectural studies. Three designs of suspension bridges were made, two with suspended side spans and one with the central span only suspended and the side cables acting merely as backstays. All were based on wire cables from which stiffening trusses with parallel chords of the Warren type were hung by means of wire rope suspenders. All towers were of silicon steel mainly and were designed to be fixed on the piers, with saddles attached and deflecting elastically. Figures 3 and 4 show these studies.

Of the three suspension bridges, as was anticipated, the one with the straight backstays proved to be the least expensive. For a comparative total length of 2,400 ft. of bridge,

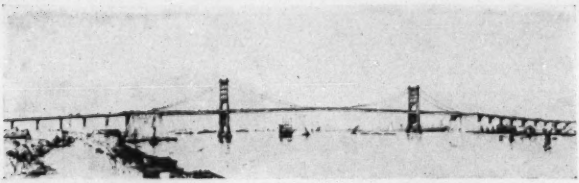
FIG. 2



anchorages included, this design was estimated to cost $6,300,000. An alternate design with short suspended side spans, each 340 ft. long, cost $700,000 more and a third design with side spans 500 ft. long cost another $700,000 more or $8,700,000. These figures have a comparative value only

and should not be taken by engineers as absolute information on the cost of similar suspension bridges. Additional comment is necessary: First, the anchorages and main piers were designed of concrete with granite facing. This facing was estimated at $100 per cu. yd. and its total cost amounted to an average of half a million dollars for the suspension bridges and the arch, the single span suspension bridge requiring two thirds of the cost of the facing of the side span type. Secondly, the entire difference in cost between the single span and the short side span suspension design is due to the high and large anchorage for the latter. Thirdly, in the longer side span suspension design the versine of the center span cable was reduced from 160 ft. to 140 ft. which, while improving the

FIG. 3.



appearance of the bridge, increased its cost. The equivalent estimate of the arch design was $6,850,000, or more than half a million dollars in excess of the cheapest suspension bridge. As the Kill van Kull bridge is designed with provision for two lines of rapid transit tracks, the greater stiffness offered by the arch was considered of advantage. The æsthetic appearance of the arch as against the suspension bridge with straight backstays also counted in its favor. It should be borne in mind that conditions at the Kill van Kull were particularly favorable to the arch design: the solid rock which is encountered at a shallow depth below water offers itself readily to the enormous thrust of the arch rib. The location required no expensive approach spans. A single arch span was, therefore, adopted.

Having settled on an arch bridge, various types of suitable arches were studied. At first a two hinged crescent shaped

FIG. 4.

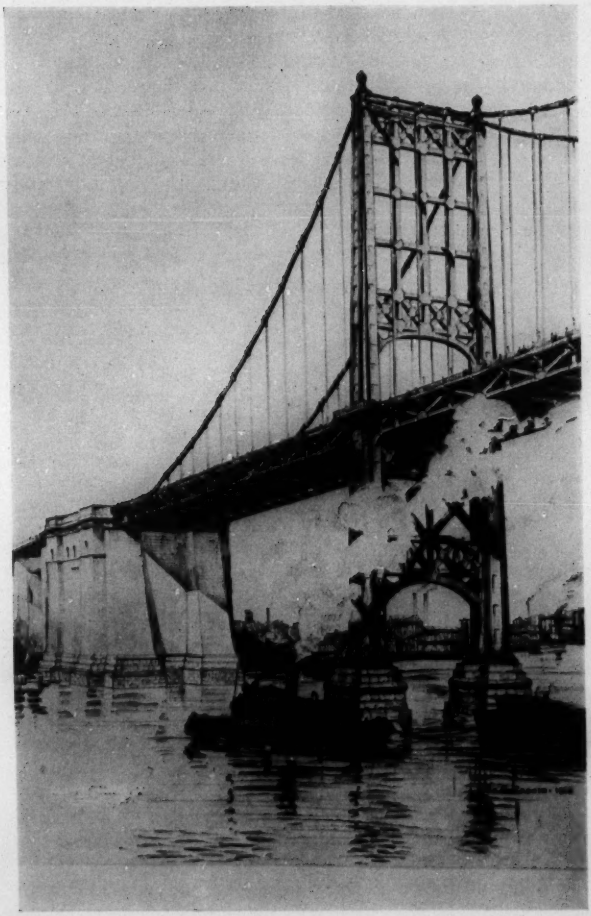
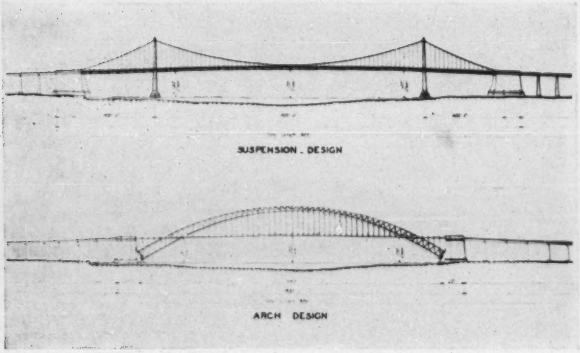


FIG. 5.

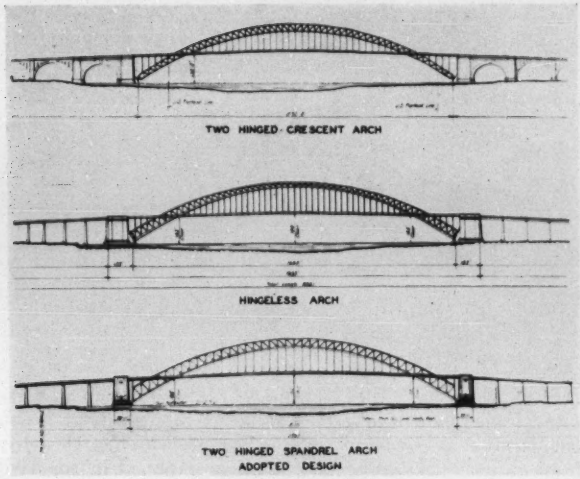


arch was developed; then various two hinged designs; finally a study was made of an arch fixed at the abutments. Much consideration also was given to a spandrel arch with a top chord entirely above the floor as is exemplified in the Hell Gate Arch and as has been adopted for the Sydney Harbor Bridge. The fixed arch brought out very interesting results.

FIG. 6.

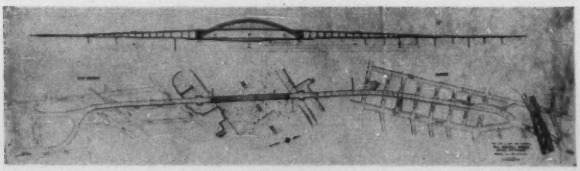
Study of Arch Designs.

FIG. 7.



The study of the effect of wind, temperature and resulting secondary stresses, together with that of the dead and live loads, as well as provision for the proper fixing at the abutments, showed that a fixed arch of this length and type offered no economic advantages and presented many design difficulties. Almost contrary to expectation, it became clear that the stiffness gained by fixing the ends of a long flexible arch is

FIG. 8.



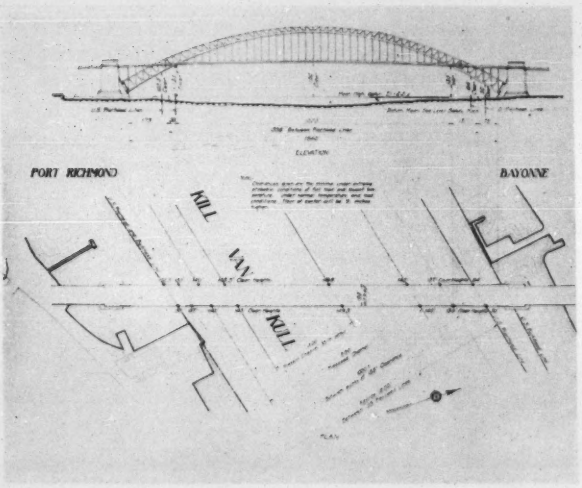
Arch as Designed.

slight and that the point of contraflexure of the arch will be found not far from the abutments.

The arch adopted, as shown on Fig. 9, is of the two hinged type with an increasing depth from crown to abutment.

It consists of trussed ribs with a depth of 37 ft. 6 in. at the crown and 67 ft. 6 in. at the ends. It has a span of 1,675 ft. between centers of bearings on piers, and of 1,652 ft. between centers of pins. The arch trusses are designed to

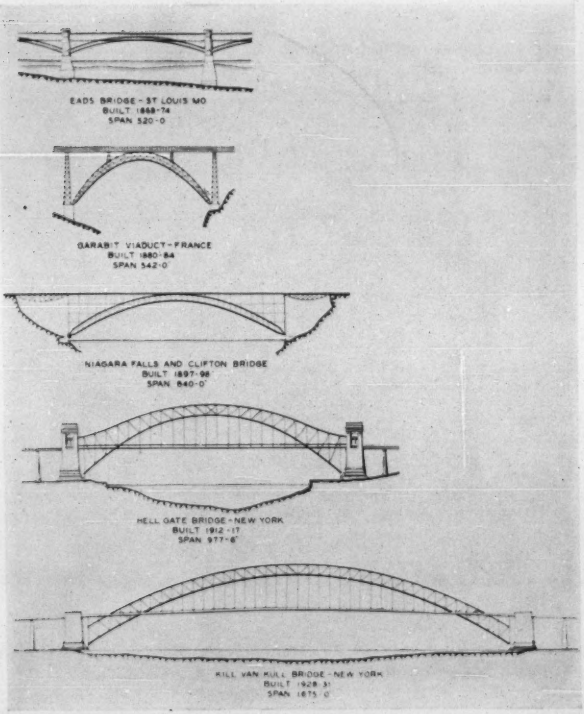
FIG. 9.



act as three hinged arches with the lower chord as continuous ribs from hinge to hinge. The lower chord has been given a parabolic curve following closely the weight of the arch polygon so that the weight of the arch steel will be practically all sustained by the lower chord and the upper chord and the bracing will act as a participating and stiffening truss merely. At a given time when most of the dead load of the bridge will be on it, the upper chord will be closed and the rib will change

from a three hinged into a two hinged arch. Thereafter, it will act under such additional dead load as may come on it, live load, temperature and wind, as a two hinged arch. The advan-

FIG. 10.



tage of so designing the arch ribs is evident. The heavy dead load is carried mainly by the lower chord and the latter can be developed into a substantial, sizable compression member of a closed form well fitted to resist compression, and sufficiently

roomy to allow of fabrication. The upper chord becomes much lighter and the forces which the long and slender web members have to sustain are much reduced. An efficient design can thus be developed with substantial economy in metal and detail connections.

A fair idea of the magnitude of the Kill van Kull arch in comparison with existing arch bridges can be had from the comparative arch bridges shown on Fig. 10. The arch which compares with the Kill van Kull is the Sidney Harbor Bridge now in construction in Australia. It has a span of 1,650 ft. When completed these two arches will offer a most interesting comparison of American and English engineering practice in design, materials and erection.

FIG. 11.

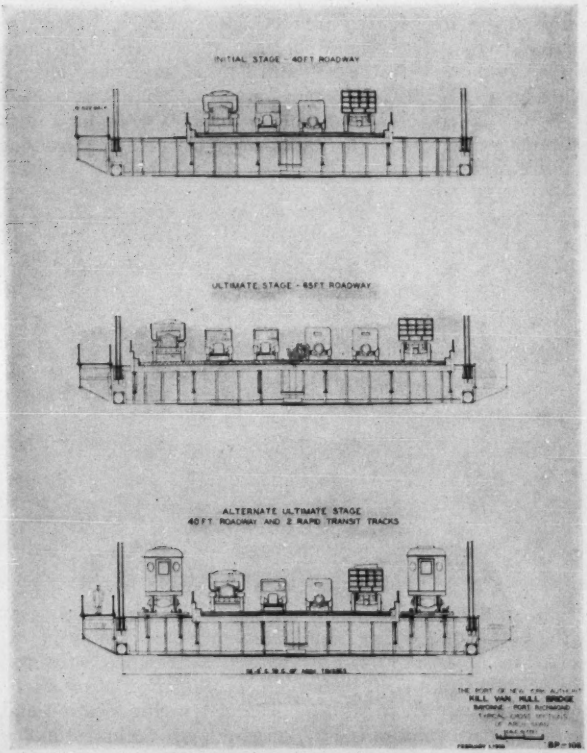
Sidney Harbor Bridge.

Comparison and Cross-Section of Bridge.

The traffic studies made for the bridge indicated that at the end of twenty years four million vehicles may be expected to cross the bridge yearly. Experience with toll bridges shows that such traffic can be taken care of by a four lane roadway 40 ft. in width. The geographic location and the prospective value of the bridge as a developer and stimulus to industry and traffic was, however, considered sufficiently important to demand a greater provision for the future. It led to the decision to build the bridge wide enough for six lanes of travel should the future traffic demand it. At the

same time studies were made of the desirability to provide for rapid transit passenger transportation. It developed that there are indications that the bridge in the future will be used

FIG. 12.


INITIAL STAGE - 40FT ROADWAY
ULTIMATE STAGE - 85FT ROADWAY
ALTERNATE ULTIMATE STAGE
40 FT. ROADWAY AND 2 RAPID TRANSIT TRACKS

extensively for passenger traffic to and from Staten Island and Manhattan by the way of Bayonne. The problem was referred to the Suburban Transit Engineering Board composed

of representatives of the transit authorities of New York and New Jersey. The board advised that the bridge be made sufficiently wide and strong to permit the installation and operation of two rapid transit tracks in addition to the four lane roadway. This was done. The cross section of the bridge accordingly has been so arranged that in the future either a six lane vehicular roadway or a four lane roadway with a rapid transit track on each side of it may be built. This has led to a distance of 74 ft. center to center of trusses

FIG. 13.

or about a twenty-second of the span, which width has been considered sufficient for the lateral stiffness of the arch.

It should be noted that both the dead and live load are different for the two alternate conditions. With the two rapid transit tracks the dead load will be 6 per cent. less but the live load will be 50 per cent. greater than if the roadway is widened to six lanes. The bridge is designed to meet both conditions.

As stated before, the rock foundation for the arch abutments was found to be not much below water, about 10 to 14

ft. on the Bayonne side, and about 18 to 25 ft. on the Port Richmond side. Both abutments have been constructed within double wall coffer dams of steel sheet-piling. They offered no unusual difficulties in construction. The coffer dam for the Bayonne abutment is shown in Fig. 13. After completion of the coffer dam, the overburden was excavated and the coffer dam unwatered.

FIG. 14.

Figure 14 shows the exposed rock foundation within the coffer dam on the Port Richmond side. The abutments are built in two parts. The first part forming the substructure of the abutments includes sufficient concrete to take care of the thrust of the arch. The second part forming the monumental abutment piers will be let in the near future.

Loads and Stresses.

The structure was designed in accordance with the "Specifications for Design of Bridges carrying highway and electric rail passenger traffic for the Port of New York Authority."

The stresses in the arch have been determined for the following stress combinations and the results have been used in proportioning the truss members.

A. Dead load, live load, impact and temperature.
B. Dead load, temperature and wind load.
C. Dead load, live load, impact, temperature and one-half wind load.
E. Dead load, one-half live load, impact, temperature and wind load.

For combination *C* and *E* a 10 per cent. increase in the unit stress has been permitted.

Broadly speaking the arch was designed for a uniform live load of 7,000 lb. per lin. ft., a temperature variation of plus or minus 55° Fahrenheit and a total wind load of 2,000 lb. per ft. of bridge, distributed; 450 lb. on upper chords, 800 lb. on lower chords, and 750 lb. on the floor system. For comparison and classification, the Kill van Kull arch may be rated as a 7,000 lb. live load bridge. This may be compared with the Manhattan Bridge having a live load of 16,000 lb. per lin. ft., the Delaware River of 12,000 lb., the George Washington of 8,000 lb. and more depending on length of load.

Allowable Unit Stresses.

The adoption of permissible unit stresses for the various members of a long span bridge presents one of the vital problems of design. For relatively short spans, we have the guidance of standard specifications developed by the coöperative efforts of engineers and adopted by practically common consent of the profession. These specifications can not be literally applied to long span bridges. The frequency of the live loads, the probable character of lateral forces, and the relation of live load to dead load must be taken into consideration. Each long span bridge demands experience and judgment to determine the proper unit stresses to be used in its design. For the Kill van Kull bridge, the following stresses were adopted:

Material.	Yield Point.	Tension.	Compression.
Carbon steel	35,000	20,000	$20{,}000 - 60\frac{l}{r}$; 17000 max.
Silicon steel	45,000	27,000	$27{,}000 - 80\frac{l}{r}$; 23000 "
Manganese steel	55,000	33,000	$33{,}000 - 100\frac{l}{r}$; 28000 "

FIG. 16.

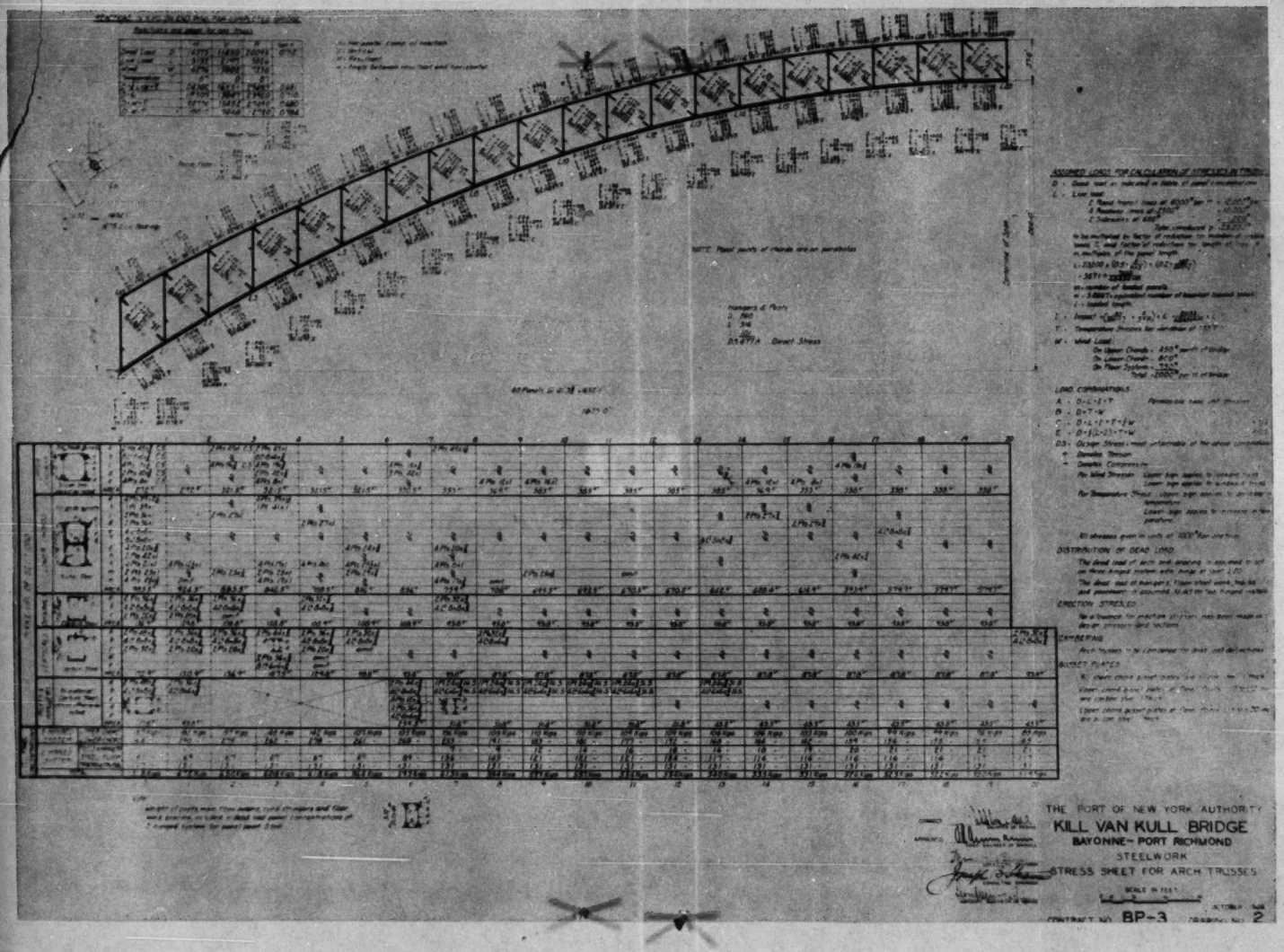
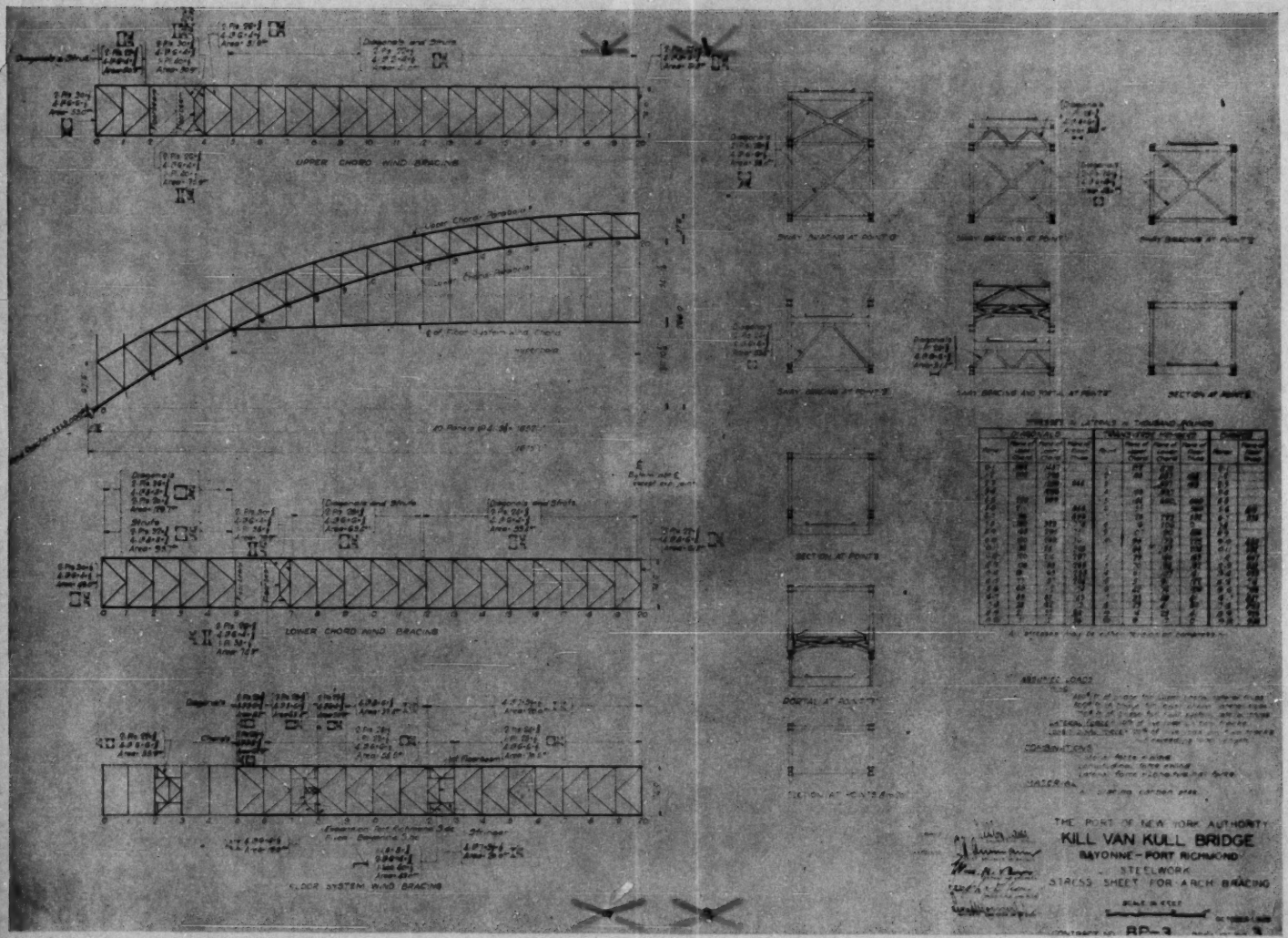

THE PORT OF NEW YORK AUTHORITY
KILL VAN KULL BRIDGE
BAYONNE – PORT RICHMOND
STEELWORK
STRESS SHEET FOR ARCH TRUSSES
CONTRACT NO. BP-3

FIG. 15.


UPPER CHORD WIND BRACING
LOWER CHORD WIND BRACING
FLOOR SYSTEM WIND BRACING
SECTION AT POINT E
PORTAL AT POINT A
SECTION AT POINTS B AND C
THE PORT OF NEW YORK AUTHORITY
KILL VAN KULL BRIDGE
BAYONNE - PORT RICHMOND
STEELWORK
STRESS SHEET FOR ARCH BRACING
BP-3

Lateral Bracing.

As the floor of the bridge intersects the arch the lateral bracing could not be made continuous. It is, therefore, arranged as a simple span for the central 24 panels resting against cantilever arms for the next 3 panels, to the intersection of the floor with the lower chord. From there on the wind reaction from the suspended floor is transmitted to the abutments by the bracing in the surface of the lower chords. The wind bracing in the surface of the lower chord presents a lateral truss with ends fixed at both abutments. Its lateral web system is interrupted between Panel Point 5 and 7 to allow for the clearances required by traffic. The shear in these panels is taken care of by proper bracing through portals and heavy hangers. In the surface of the upper chord there is a continuous lateral bracing for the major portion of the arch to Panel Points U-4 where the web system is interrupted to provide for required clearances. Here again the lateral shear is taken care of by portals and transverse bending of the chords and sway bracing.

Stress Analysis.

The analysis of arches subject to vertical loads has been much studied and sufficient mathematical apparatus is available to determine to any reasonable degree of accuracy the stresses and strains in the trusses due to such loads. Observations made on the behavior of arches under vertical loads have usually verified the analytical methods. An arch bridge is, however, not merely a frame acting in a plane but it is a structure in space, and a deformation of one plane or surface effects considerably the other constituent planes. Not much research is known to have been made in this direction. The effect of lateral, or horizontal, loads, such as wind, upon an arch structure has not been fully analyzed nor are any experimental data available. A thorough analytical study was made for the Kill van Kull arch and it was thought necessary to verify the results of the contemplated analysis by observation on a model.

Complete calculations were made of the secondary stresses in the arch trusses due to its rigid connections. A study was made of the fixing effect of the secondary stresses resulting from the friction of the end pins. As was to be expected, the

gradual curvature of the elastic line of an arch of this kind, as well as the arrangement of the vertical web system, developed no important secondary stresses.

The friction of the pins at the abutments which act as the hinges of the arch was assumed to have a frictional coefficient of 30 per cent. For this value the secondary stresses in the end member of the bottom chord were found sufficiently high to call for an addition to the section of member of about 50 sq. in. The effect of hinge friction gradually vanished with its distance from the abutments.

Effect of Vertical and Horizontal Distortion of the Arch.

In truss systems which abut, or are tied at their ends to, rigid bodies so that they exert in addition to a vertical reaction also a horizontal one, the stresses are affected by the vertical or horizontal displacements of the system. Such systems are suspension bridges and arches. In a suspension bridge the vertical and horizontal distortions due to the outside causes on the bridge generally reduce the stresses in the stiffening trusses. In arches, on the contrary, these distortions increase the primary stresses. The heavier a suspension bridge is and the more its deflection, the more will be the relief it will afford to the stiffening truss; the heavier an arch is and the more its deflection, the more will be added to its primary stresses. It was thought necessary to obtain a measure of the magnitude of these additive stresses in the Kill van Kull arch. It was assumed to be justified to analyze these stresses separately for the vertical and horizontal deflections and to superimpose their results algebraically. The absolute value of these stresses was found to be small.

The vertical deflections caused by live load and temperature result in the highest additive stresses near the quarter point of the arch. They reach there 500 lb. per sq. in. in the lower chord and 1,000 lb. in the upper chord.

The vertical forces and the longitudinal thrust also tend to increase the lateral deflections due to wind and thus cause additional stresses in the arch rib. These additive stresses reach their highest value at mid-span and amount to 800 lb. per sq. in. in both the lower and upper chords.

The combined additive stresses due to the vertical and horizontal deflections of the arch show nearly a constant value

from quarter point to mid-span and do not exceed 1,000 lb. per sq. in. in the lower chord and 1,500 lb. per sq. in. in the upper chord. These stresses gradually decrease from the quarter points to zero in the abutments. The additive stresses in the web members are all within 1,000 lb. per sq. in. The additive stresses may serve as a measure of the stiffness of the arch vertically and laterally. Because these stresses are produced under exceptional conditions of loading, they were thought not of sufficient magnitude to increase the sections of the members.

Observations on Test Model.

To check physically the results derived from theoretical investigations and particularly to determine the more specific problems, such as the behavior of the portals in transmitting wind stresses, and the efficiency of sway bracing distributing unsymmetrical loads between the two arch ribs, a model of the Kill van Kull arch was made. It was a proportional replica of the arch reduced in the ratio of 1 to 192, making the model about 9 ft. long. Engraver's brass of uniform quality was used. Test specimens, subjected before testing to the temperature required for soldering, developed the following elastic properties: Proportional limit 9,000 lb. per sq. in.; yield point 15,000 lb.; modulus of elasticity 13,900,000. The model therefore was subjected to loads which did not cause unit stresses in excess of 8,500 lb. per sq. in. so as not to exceed the proportional limit. The built up sections of the full sized structure were represented in the model by solid members. Considering the modulus of elasticity of the two materials, steel and brass, the model was found to be twice as rigid as the full sized arch. The areas of all members were reduced in the same ratio, so that the proportional behavior of the two structures was not effected.

The strains in the members were measured by Huggenberger extensometers which magnify the strains 1,200 times. The distortions were registered by gauges of the Berry type graduated to read to 1/1,000 of an inch. Each individual test was repeated several times to eliminate errors in reading the instruments. Influence lines of strains and deflections as well as the effects of full and partial live load were studied for

FIG. 17.

equal and unequal loading of the two arch ribs. The behavior of the arch under action of horizontal loads was investigated.

To evaluate the results, a complete theoretical analysis of the model was made based on the same assumptions as those used in the design of the full sized structure, so that it was possible to make direct comparison between the physical tests on the model and the computed results based on the geometric and elastic properties of the steel arch.

Diagram 1 in Fig. 18 shows the influence line for deflection at P.P. 6 under equal loading of both ribs.

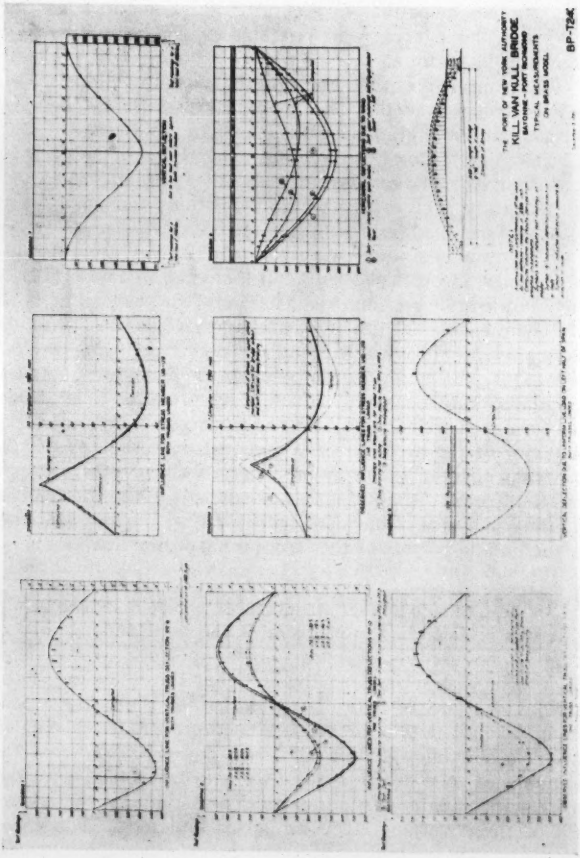
Diagram 2 shows influence lines for deflections at P.P.10. The two outer curves give the observed and theoretical values for equal loading of both trusses, the sway braces are thus not called upon to act and each rib sustains one half of the full load applied to it. The test then was repeated with one rib only loaded. This, of course, was done to determine the effect of the sway braces on the distribution of the load. Two curves, both observed, are plotted, one giving the effect on the distribution of the loads for sway braces in P.P. 0 to P.P. 5 and the other for sway braces throughout. It will be noted that the differences between the two curves is slight. In the first case the sway braces reduce the downward deflection of the loaded truss to about 60 per cent. and in the latter to about 55 per cent. Sway braces between the arch portals consequently better the distribution by only 5 per cent. and their omission is fully justified. To reduce the deflection to 60 per cent. means that the unloaded truss is forced to carry 40 per cent. of the load, thereby relieving the loaded truss. Similar tests for other points of the arch confirmed these facts. It should be added that for points toward the center of the arch the transmission of load decreases somewhat while the opposite is true for points closer to the abutments.

The sway braces from P.P. 0 to P.P. 5, as placed in the final design, are of great importance in distributing the stresses and equalizing the deflections between the two arch ribs in all cases of unsymmetrical loading.

Diagram 3 represents a supplementary illustration to Diagram 2. It gives the distribution for one sided loading in a more explicit form.

Diagram 4 shows the influence line for stress of member

FIG. 18.



U8 – U9. This test is included to demonstrate the close agreement between physical and analytical results.

Diagram 5 gives influence line for stress in member U12–U13 for equal loading of arch ribs and for one truss only loaded. The curves represent similar conditions as those shown in Diagram 3.

Diagram 6 gives the deflection for partial live load, 20 1/2 panels being loaded. The greatest discrepancy between physical and analytical result is less than 4 per cent.

Diagram 7 shows the vertical deflections of the arch for uniform live load over the entire span.

Diagram 8 gives horizontal deflections for partial and total uniform load, representing horizontal wind pressure.

The tests as a whole were very satisfactory and not only verified the theoretical results but added also considerably to our knowledge regarding the behavior of the structure.

The measures of the deflection and stresses on the model have proven to be entirely reliable. Where the values are not effected by the action of the bracing, the agreement between calculated and measured values is remarkable. The model has furnished a clear insight into the stress action and elastic behavior of the arch. It has demonstrated the remarkable stiffening effect of the sway bracing near the ends of the span and its effect in distributing one-sided loads to the two trusses. At the same time it has demonstrated that the sway bracing in the middle portion of the structure is of but small value.

Materials.

In designing a major structure of the magnitude of the Kill van Kull arch, the problem of the kind and quality of steel to be used is of paramount importance. Advanced engineering has recognized the fact that the functions of the various portions of a bridge, and that of their constituent members and details, demand sometimes greater strengths and at other times greater stiffness. It has realized that the demands of good design require the utilization of the various grades of available structural steel and that by the proper use of these various steels, a better and more economical structure can be built. Modern design, therefore, utilizes steels of various strengths. Where usual stresses have to be met and where stiffness is of importance, the common struc-

tural carbon steel is used. Where greater forces have to be sustained, silicon steel is generally utilized. Finally, where exceptionally high forces have to be met and the members become excessively bulky, high alloy steels are introduced.

For the Kill van Kull bridge materials of the following strength requirements were specified:

	Minimum Yield Point.	Minimum Ult. Strength.	Permissible Unit Strength.	
			Tension.	Max. Compr.
Structural carbon steel	35,000	58,000	20,000	17,000
Silicon steel	45,000	80,000	27,000	23,000
High alloy steel	55,000	90,000	33,000	28,000

In the arch the main material of the lower chord is high alloy steel throughout; that of the top chord silicon steel, except the three end panels which are carbon steel; the web members are all carbon steel, except some which were made of silicon steel because of erection stresses, all lateral and sway bracing is of carbon steel.

The make up of the chords is shown on Fig. 19.

The contract bids for the high alloy steel called for 3 1/4 per cent. nickel which had been used successfully in several large structures. The specifications provided, however, that the contractor might substitute for the nickel steel, subject to the approval of the Chief Engineer, another steel which shall meet the physical requirements for nickel steel and in all other respects be equivalent in quality. The American Bridge Company was the lowest bidder and was awarded the contract. It offered as an equivalent substitute for nickel steel a carbon manganese steel of the following composition and physical qualities:

SPECIFIED CHEMICAL PROPERTIES.

Carbon	max. 0.40;[a] preferably not over 0.35
Manganese	" 1.80
Phosphorus	" 0.04 [b]
Sulphur	" 0.05 [b]
Silicon	" 0.10 to 0.30 [a]

[a] An excess of 10% permitted on check analysis.

[b] An excess of 25% permitted on check analysis.

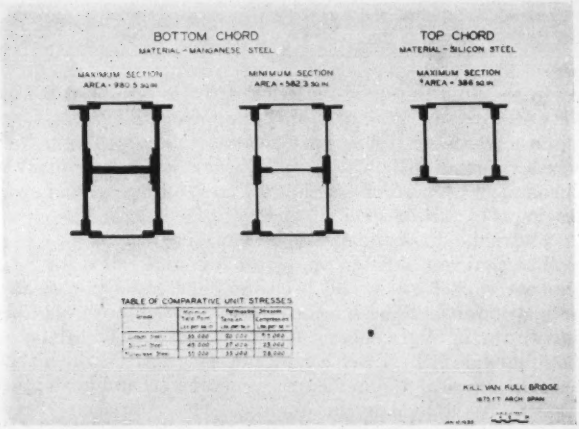
SPECIFIED PHYSICAL PROPERTIES.

Yield Point	55,000 Minimum
Ultimate Strength	90,000 "
Elong. % in 8"	1,600,000/Ult. Stre.[a]
" " in 2"	18.0 Minimum
Reduction of Area %	30.0 [a]

[a] For mtl. over 3/4" deduct 0.25% for each 1/16" to a min. of preferably 14%, but not less than 13%.

[b] For mtl. over 3/4" deduct 0.50% for each 1/16" to a min. of 24%.

FIG. 19.



This steel was offered at a reduction in price below that of nickel steel of 3/4 cents per pound, or about $80,000. After careful investigation, which included tests from a heat specially rolled for the purpose, adoption of precautionary provisions and more rigorous requirements regarding testing and inspection, the Port Authroity permitted the use of manganese steel in substitution for nickel steel.

Typical stress-strain curves of carbon manganese, silicon and carbon steels are shown on Fig. 20.

The properties of the carbon manganese steel manufac-

tured by the Carnegie Steel Co. for the American Bridge Co. are of great interest and are indicated in the following:

The average results obtained on the standard tests of 168 melts of manganese steel rolled for the chords of the Kill van Kull arch span were:

Number of Melts	168
" " Tests	968
Analysis: C, 0.33; Mn, 1.63; Si, 0.18	
Yield Point	58,600 lbs./sq. in.
Ultimate Strength	101,600 " " "
Elongation in 8"	19.5%
Reduction of Area	42.6%

The yield point given above (58,600 lbs./sq. in.) is the commercial yield point or drop of testing machine beam.

The following results were obtained on twelve (12) check test specimens selected from among the melts included in the above list. These were accurately machined specimens (about ½" in diameter) and were tested in the laboratory of the Port Authority.

Elastic Limit	46,000 lbs./sq. in.
Yield Point	59,300 " " "
Ultimate Strength	102,530 " " "
Elongation in 2"	23.1%
Reduction of Area	51.7%

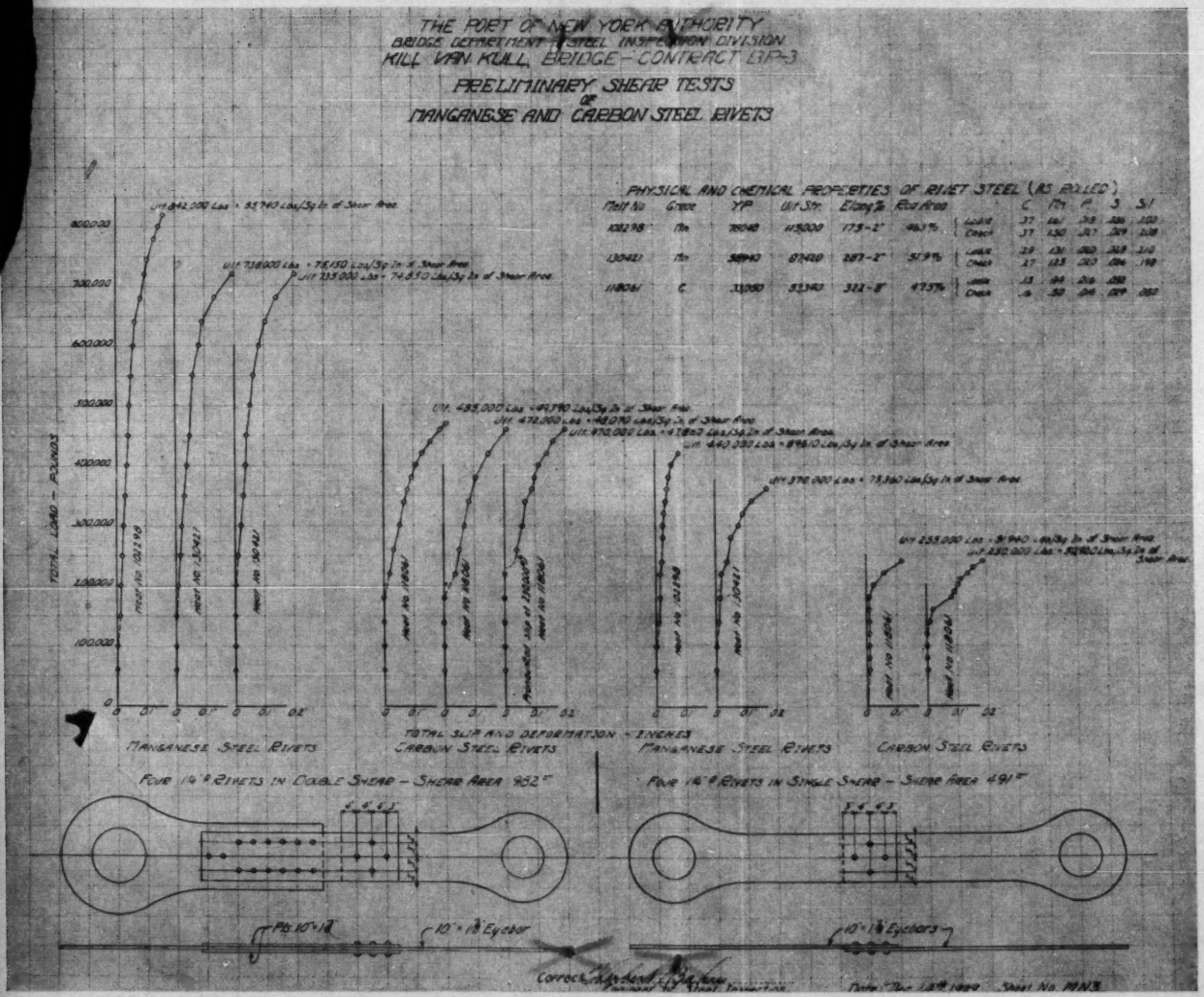
The elastic limit given in the above table is according to Johnston's "Materials of Construction" and is the point on the stress-strain diagram at which the rate of deformation is 50 per cent. greater than at its origin.

None of the manganese steel used in the Kill van Kull Bridge was heat-treated; it was all used in the "as rolled" condition.

The manufacture of the manganese steel has shown that much care has to be exercised and that the heavier plates are apt to encounter difficulties and develop cracks. Large size tension tests have given poor results and it was finally decided not to use carbon manganese steel in tension members of the bridge.

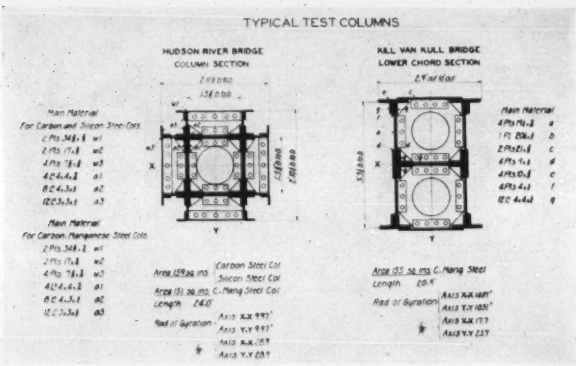
A series of tests of large size columns was undertaken by the Port Authority jointly with the U. S. Bureau of Standards.

FIG. 20.


THE PORT OF NEW YORK AUTHORITY
BRIDGE DEPARTMENT - STEEL INSPECTION DIVISION
KILL VAN KULL BRIDGE - CONTRACT 13P-3
PRELIMINARY SHEAR TESTS
OF
MANGANESE AND CARBON STEEL RIVETS
PHYSICAL AND CHEMICAL PROPERTIES OF RIVET STEEL (AS ROLLED)
Mill No
Grade
Y.P.
Ult. Str.
Elong. %
Red. Area
C
Mn
P
S
Si
TOTAL LOAD - POUNDS
TOTAL SLIP AND DEFORMATION - INCHES
MANGANESE STEEL RIVETS
CARBON STEEL RIVETS
MANGANESE STEEL RIVETS
CARBON STEEL RIVETS
FOUR 1 1/4" Ø RIVETS IN DOUBLE SHEAR - SHEAR AREA 982"
FOUR 1 1/4" Ø RIVETS IN SINGLE SHEAR - SHEAR AREA 491"
Pls. 10" x 1/2"
10" x 1/2" Eyebar
10" x 1/2" Eyebars
Corrock Eyebars
Note: "Dec 18th 1929" Sheet No. MN3

The object was to observe the behavior and failure strength of large columns of the types used in the Hudson River and Kill van Kull bridges. Columns with cross sectional areas of 144 to 159 sq. in. were built and practically required the full capacity of the Bureau's 10,000,000 lb. testing machine. Two manganese steel columns were dimensionally one-half size of the Hudson River columns and two of the Kill van Kull lower chord. The strongest column, of carbon manganese, developed an ultimate resistance of 9,653,000 lb.

FIG. 21.



The ultimate compressive strength of the carbon manganese columns was from 58,650 to 62,280 lbs. per sq. in. The column strength was thus found to be the yield point strength of the material in the members. These columns, therefore, met the fullest expectations as did all the others. Figure 22 shows the secondary buckling failure of cover plates in one of the columns.

These tests on the largest columns ever made were conducted with great scientific care and have furnished most valuable information. A preliminary description has been published by R. S. Johnston, Engineer of Research, in *Engineering News-Record*, Dec. 26, 1929. The complete report will be published by the Bureau of Standards.

The American Bridge Co. also proposed to use carbon manganese steel for field rivets instead of common carbon steel rivets. The manganese rivets were made slightly softer than the rolled plates and shapes. The yield point was lowered to 47,000 lb. and the ultimate tensile strength to 82,000 lb. per sq. in. After a study of the tests made on riveting, filling of holes and shearing resistance, the use of manganese rivets was permitted and adopted.

FIG. 22.

The illustration shows the results of the shearing tests and affords a comparison between manganese and carbon rivets. Based on the results of the tests, a shearing stress of 22,500 lb. per sq. in. was allowed for carbon manganese rivets or 50% higher than on carbon rivets, the actual strength of the rivets being 60% higher.

The importance of having introduced a rivet material of higher strength which shows all the better qualities of the common carbon rivet deserves the attention of engineers. The reduction in cost of field riveting and in the size of gusset and splice plates is of material advantage in economy and efficiency of design.

Forged Bearing Blocks.

In long span bridges the reaction points are called upon to sustain enormous loads. The design of efficient and dependable bearings presents a serious task to the engineer. Castings frequently weighing 40 tons or more are required. The difficulties encountered in making large steel castings are well known. These difficulties increase with size. Not infrequently engineers are compelled to reject castings weighing many tons and costing thousands of dollars. There is a manifest need for a more dependable material to sustain the enormous loads of the long span bridges of today. With this in view, the bearing blocks of the Kill van Kull have been made of forged steel of simple outline.

The lower chord abuts against a bearing block which in turn bears on a 16 in. pin. The pin again bears against a lower block. These blocks are 7 ft. by 10′ 8″. The upper block is 3 ft. thick and the lower 4 ft. The larger block weighs 59 tons. The blocks have the duty to distribute about 15,000 tons through the pin. Their efficiency and dependability is of the utmost importance. They were furnished at a price not exceeding that of casts teel. Figure 24 shows a complete bearing being fitted to the pin in the shop.

Hangers.

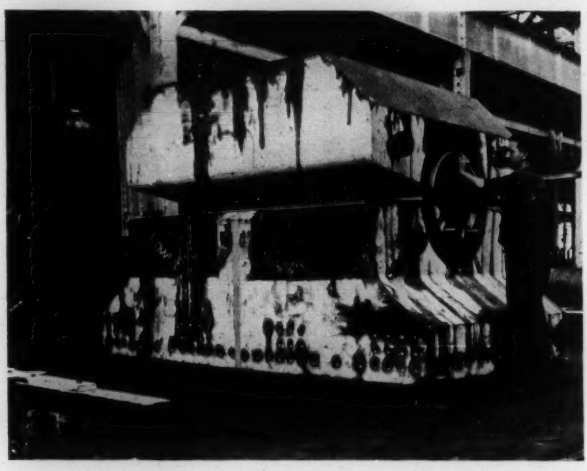
In the central portion of the arch the floor is suspended from the lower chord. This results in hangers short and long. The longest are 125 ft., the shortest 24.5 ft. Traffic and wind at times set up vibrations in the longer hangers which may cause excessive stresses in the metal. Again, the longitudinal and lateral displacements of the floor relative to the upper chord of the bridge cause bending and tortional stresses in the shorter hangers. Originally, the contract design called for stiff hangers built up of shapes. Subsequently, in a neighboring city in a similar but much smaller arch bridge with the floor suspended, the structural steel hangers failed in several instances. The use of structural steel hangers for the Kill van Kull arch was then reconsidered by the engineers and the change was made from structural steel to wire rope hangers.

The hangers consist of 4 wire ropes of the type common in suspension bridges. To reduce as much as possible the effect of the elongation of the rope due to its higher unit stress

and less stiffness as compared to structural steel hangers, as large a size as 3 1/4 in. diameter rope was used. They were prestretched to give a minimum modulus of elasticity of 20,000,000 lb. Four full sized ropes were tested to failure and with remarkable uniformity developed a strength of 1,000,000 lb. each.

As far as the speaker knows this is the first time that wire ropes have been used as suspenders in other than suspension bridges.

FIG. 24.



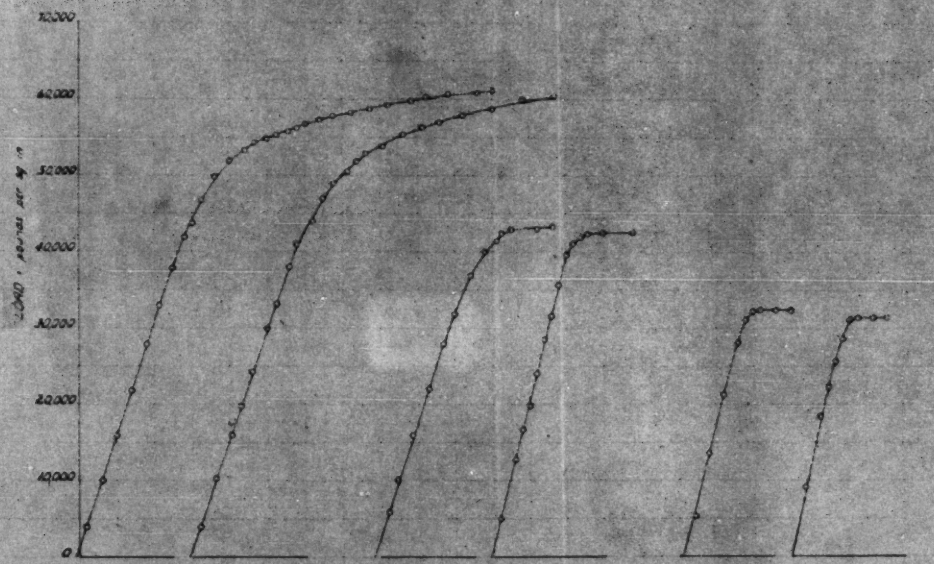
Erection of Arch.

The contract permitted the contractor freedom of choice of the scheme and method of erection. And this is as it should be: the contractor carried the entire responsibility for the safe and successful execution of the work, and he pays for it. The credit for the erection of the Kill van Kull arch should go to the American Bridge Co. and its engineers. The engineers of the Port Authority have coöperated with the contractor, checked the erection structures, the loads, the expected deflections and measured the strains at critical points. The erec-

FIG. 23.

THE PORT OF NEW YORK AUTHORITY
BRIDGE DEPARTMENT — STEEL INSPECTION DIVISION
KILL VAN KULL BRIDGE — CONTRACT BP-3

TYPICAL STRESS-STRAIN CURVES FOR MANGANESE, SILICON AND CARBON STEELS

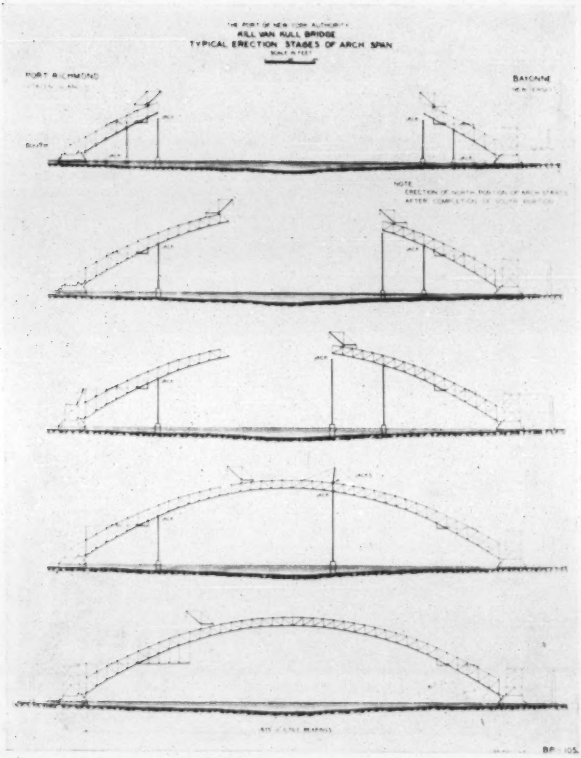


Melt No.	14329	14368	21268	313175	43284	51331
Slab No.	202321	225297	185385	—	—	—
Material	1¼ U.M. Plate	1½ U.M. Plate	1" U.M. Plate	6×6×½ Ang.	8×8×½ Ang.	6×6×½ Ang.
Check Tests (across grain) — Ult. Str.	106,420	105,970	89,120	83,180	63,250	59,780
Check Tests (across grain) — Yield Point	61,500	61,000	43,900	43,000	32,880	31,820
Std. Mill Tests — Ult. Str.	107,400	110,700	91,740	92,040	63,150	60,000
Std. Mill Tests — Yield Point	58,150	61,060	50,120	49,840	37,740	37,610

Correct: [illegible]
Engineer of Steel Inspection

Date: Jan. 11th 1930 Sheet No. 17NG

FIG. 25.

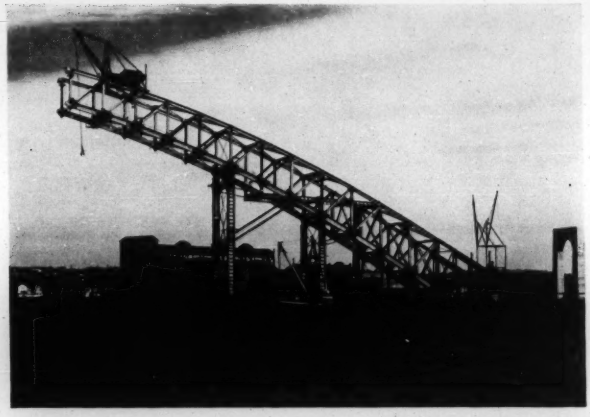


tion of the arch well planned and carefully executed, was a great engineering accomplishment. It is ably described in a monograph by Henry W. Troelsch, designing engineer of the American Bridge Co., published by the latter.

The writer will confine himself to the mention of the most salient points in the erection of the arch.

Because the Department of War required the main channel to be open for navigation at all times and that channel is located south of mid-span, an unsymmetrical erection arrangement was compulsory. The south portion of the arch was erected extending for 14 panels and the north portion extended for 26 panels. The contractor adopted a falsework method of erection with the rib resting on steel bents at various points and cantilevering beyond the points of support as erection progressed. Ten bents were used and the rib was

FIG. 26.



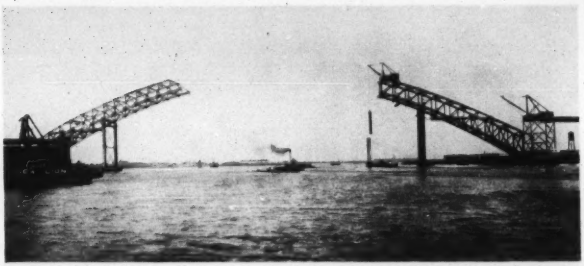
cantilevered successively from bent to bent at Panel Points 1, 2, 4, and 7 on the south side and at 1, 2, 4, 7, 11 and 16 on the north side. Bents 1, 2 and 4 were reused. The Port Richmond side was completed first and then the Bayonne side was started.

As the erection progressed each bent was released from the load after the arch was safely on the farther bent. The reaction on the bent at Panel Point 11, however, was maintained at the same time as that on bent 16 until the arch was ready for closure.

Jacks were provided at alternate bents and all lifting was done by these jacks with shims immediately following the displacement. All joints were 60 per cent. drift pinned, the remaining holes being bolted. Riveting followed closely behind.

The founding of the bents was made dependable by the rock floor of the estuary. No settlement of the foundation on which the bents rested was expected and none occurred. The bents on the south side rested on what may be termed solid cribs dropped to the rock. The bents themselves were made of floor beams which afterwards formed part of the south approach and other bridge members.

FIG. 27.



The greater distortion of the north portion during erection near bent 16 demanded much increase in upper chord sections and would have caused undesirable secondary stresses in the lower chord. The rib was, therefore, stiffened at that point by a toggle joint, which properly jacked relieved the stresses. It can be seen on Fig. 28.

The two branches of the arch met within 1 inch. Closure was effected efficiently and promptly.

Conversion to Two Hinged Condition.

After closure, the arch was in a three hinged condition with a hinge at lower chord P.P. L-14 and the upper chord member U-13 U-14 missing. It was then in order to convert it into a two hinged arch. As stated before, the design was made as a three hinged arch for the weight of the arch rib

and bracing with a hinge acting at the crown in the lower chord. For all subsequent stages, the arch was to be two hinged. The compressive stress in the top chord closing member U-13 U-14 was, therefore, computed in accordance with these assumptions. But instead of forcing the stress into the member directly by jacking, an upward force at Panel Point L-7 of the south portion was applied by jacking and the closing member was inserted at zero stress. The upward force was computed to be that force which, if acting on the completed two hinged arch, would reduce the stress in the closing member to zero. This was computed to be 660,000 lb. at the normal temperature of 55° F. In all computations

FIG. 28.

for deflections allowance was made from 6 per cent. to 9 per cent. for splices and details in the various members. The applied upward force was checked by measuring the prefigured deflection and by strain gauges reading on the upper chord U-6 U-7 above the jacked joint. A change of stress of 5,080 lb. per sq. in. was computed. The actual equivalent measured was 4,980 lb. With the addition of loads on the arch during the further erection strain measurements were taken on the closing link and were found to be within 100 lb. per sq. in. of the computed stress. These checks and observations give us the assurance that the actual dead load stresses are very close to those computed.

The contract for the arch called for payments on the steel as required for the bridge and as shown on the contract drawings. All additional steel that may be required for purposes of erection and either left in the structure or afterward removed was to be furnished by the contractor without charge as part of his undertaking. The total amount of additional steel required for the erection of the arch was not more than 145 tons. Of this, 75 tons remained permanently in the structure and 70 tons was temporary. The work on the arch erection began November 1929 and the arch was closed in October 1930. The method for the erection of the arch adopted by the American Bridge Co. thus proved to be both efficient and economical.

FIG. 29.

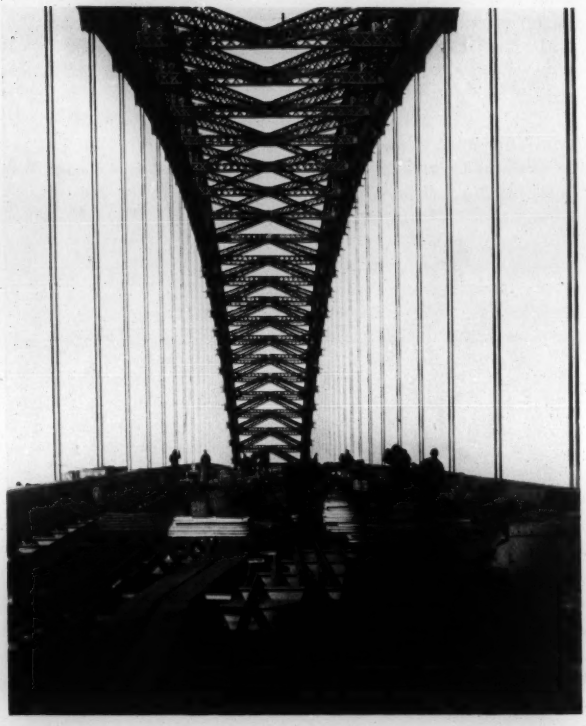
Figure 29 shows the arch closed, the suspenders hung and the mid portion of the floor being erected.

Figure 30 gives a view from the floor of the arch looking toward the abutment.

The writer has confined himself to the main structure of the bridge. He has thought it advisable not to encumber the paper with the description of the approaches.

Figure 31 gives an idea of the character of the approach which consists of long plate girders on concrete piers.

FIG. 30.



The steel in the main structure is:

Carbon manganese	10,500,000 lb.
Silicon steel	7,300,000 lb.
Carbon steel	14,900,000 lb.
Forged steel	800,000 lb.
Wire rope	500,000 lb.
TOTAL	34,000,000 lb.

There is a total tonnage of 17,000 tons of steel in the main structure and 9,250 tons in the approaches, or practically 26,500 tons in the entire bridge.

It is of interest to note that the cost of the steel in the entire bridge, arch and approaches, averages 9 1/2 cents a pound.

The total estimated cost of the initial stage of the Kill van Kull bridge, including financing, was $16,000,000. At the present time the bridge is completed and under operation. The only important work left to be done is the monumental masonry piers forming the upper portion of the abutments.

FIG. 31.

The final estimated cost of the completed bridge can, therefore, be closely foretold. The actual cost of the bridge, including real estate, engineering, administration and interest, and financing, will be 14 per cent. below the original estimate.

The Kill van Kull bridge, recently named officially the Bayonne Bridge, was opened to the public on November 14th, 1931.

The bridge was planned and built under the direction of Mr. O. H. Ammann, Chief Engineer. It is the result of the coöperative efforts of the engineers of the Port of New York Authority to whom the credit for this work is due.

A PIEZO-ELECTRIC GAGE FOR RECORDING THE INSTANTANEOUS PRESSURE IN SHOTGUNS.

BY

C. T. ERVIN,

Chief Physicist, The Peters Cartridge Co., Kings Mills, Ohio.

The importance of time-pressure records in ballistics has long been recognized. Due to the complications of recording such curves, imposed by the inertia factors of various apparatus, this work has been rather slow until recent years. Even today practically all of the sporting arms have never had time-pressure records made to show their characteristics. It is evident, even to those unfamiliar with ballistic problems, that such records will reveal much information about the character of the powder that is to be used with various loads and the primer to be used with the various types of powder.

Various methods have been used to record pressures in ordnance and small arms but practically all of them have serious inertia factors which impair their use. A calibrated stiff spring, having a small mass, has been used by A. G. Webster and L. T. E. Thompson to record pressures, but such an instrument is not convenient to operate and the records are sometimes difficult to analyze. Lead or copper crusher cylinders, which are compressed by a piston acted upon by the propelling gas, are commonly used to give an indication of the maximum pressure developed in guns. These are the gages which are used in factory production work, to serve as a guide in guarding against the loading of ammunition having dangerously high maximum pressures. Of course, these gages give no indication of the rate of increase or the rate of decrease of the pressure. They do not necessarily give a reasonably accurate indication of the maximum pressure developed since their indications change with the rate of increase of the pressure.

The only entirely successful method of recording pressure variations in all types of small arms, at the present time, is the

piezo-electric method. This method was suggested by Dr. G. F. Hull and Capt. H. O. Wood. Dr. Karcher used a ballistic galvanometer connected to the opposite terminals of a series of quartz crystals and recorded the motion of the galvanometer. The differential of the curve which the galvanometer coil traced on a moving film with a time scale gave a curve proportional to the time-pressure curve. It is seen that this method will involve an extra procedure to produce the curve desired. The direct plotting of the time-pressure curve is possible, however, if the piezo-gage is connected to a resistance-coupled amplifier similar to the one suggested by Dr. G. F. Hull. This is the type of apparatus used by Dr. Kent in obtaining time-pressure records on ordnance and on some small arms. The same general type of apparatus has been used in a modified form by the Physical Laboratory of The Peters Cartridge Company in obtaining time-pressure records of shotgun performance. The clear bakelite case which holds the elements of the gage, and at the same time affords easy inspection, was suggested by Dr. R. H. Kent. The apparatus was constructed by the personnel of the Physical Laboratory.

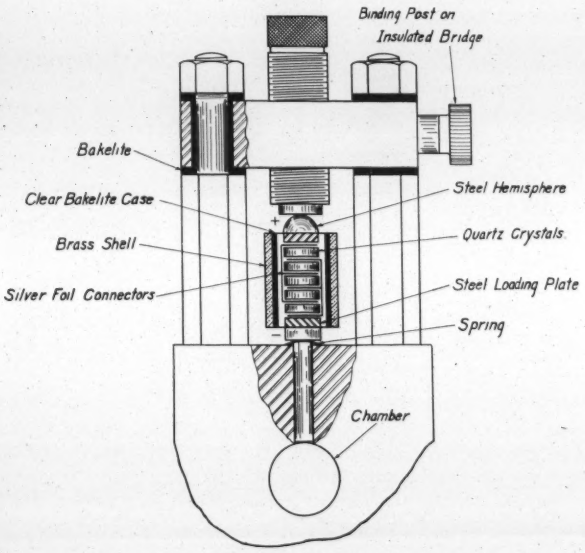
The complete pressure recording apparatus consists of: a firing mechanism with provisions for transmitting the chamber pressure to a piezo-gage; the piezo-gage proper; a resistance-coupled amplifier to convert the charge developed by the gage to a measurable current, and an oscillograph-camera combination to record the current variations. Auxiliary equipment includes apparatus for the direct calibration of the gage, amplifier and oscillograph, as a complete unit.

The pressure gun is essentially a standard pressure shotgun with changes such as: insulating the restraining bridge in order that it may serve as one of the contacts for the gage, and providing facilities for the calibration of the gage. Figure 1 illustrates the manner of assembling the gage in the gun for taking pressure records. Figure 2 is a photograph of the complete gun, assembled to take a record.

The piezo-gage was assembled, as shown in Fig. 1, from quartz crystals having piezo-electric properties. When these crystals are stressed, by applying pressure to the opposite faces, which are cut perpendicular to the electric axis of the crystal, a definite quantity of electricity is liberated. This

charge is proportional to the stress, throughout the range used, and was determined experimentally as described later. The crystals are connected by means of silver foil so that the negative sides of all of the crystals join a common conductor. In like manner the positive sides are connected to a common conductor. The charge delivered by the two connectors is the

FIG. 1.



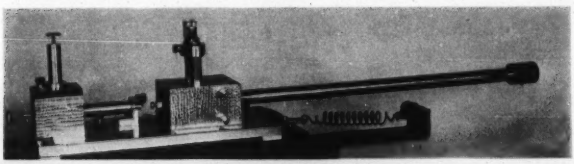
Drawing to illustrate the installation of the piezo-electric pressure gage for measuring chamber pressures in shotguns.

sum of the individual charges liberated by the crystals and the complete gage will supply a definite total charge depending on the force applied to it. In like manner, if a given load is released from the gage, a charge of opposite polarity and equal quantity is developed. It is this charge, with its voltage limited by an added condenser, which is used as a measure of the pressure on the gage. The voltage developed by the gage

will depend on the capacity and charge in the circuit. A definite capacity is introduced to make the voltage range of the combination come within the voltage range of the amplifier.

Figure 3 is a photograph of two assembled piezo-gages. One is encased in a brass shell, to protect it during handling, and the other is shown assembled in the same manner except that the brass case has been removed. Note that the gage is loaded by means of a steel hemisphere. Steel plates at either end transmit the load to the crystals and are permanent parts of the gage. The clear bakelite case affords easy inspection of the gage as well as insulation protection. This enables the operator to remove the gage and handle it without danger of shifting the plates. It will be noted by examining Fig. 1

FIG. 2.



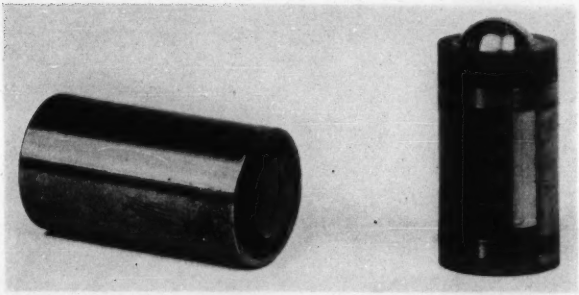
Photograph of pressure gun used in taking pressure measurements by the piezo-electric method.

that the negative side of the gage is connected to ground through the piston and spring, whereas the positive end is connected to the restraining bridge which is insulated from the gun by means of bakelite.

The charge, developed by the gage, is transmitted to a condenser, to limit the voltage, which is connected to a three-stage resistance-coupled amplifier similar to that suggested by Dr. Hull. The leads are protected by armor to shield them from induction voltage effects from other circuits. The output of the amplifier is connected to an oscillograph of the vibrator type. The motion of the oscillograph element is recorded on a spiralling drum oscillograph camera constructed for the Physical Laboratory of The Peters Cartridge Company by the late Captain Philip P. Quayle.

The details of the calibration of the apparatus, and the recording of shotgun pressures, are outlined in order to show the relation of the calibration to the final record. The three-stage resistance-coupled amplifier, shown in Fig. 4, was adjusted in such a manner that the output current was directly proportional to the input voltage. The meters shown in the photograph enable the operator to maintain the proper operating conditions, once they have been established. If the voltages on the tubes are held constant there is no change in the amplifier calibration unless the tubes change their characteristics. This has been closely checked, by means of

FIG. 3.



Photograph of two assembled piezo-electric gages. One gage is encased in a brass shell as it is normally used. The other gage has the brass shell removed to enable inspection of the gage. Note the steel plates at each end of the crystals.

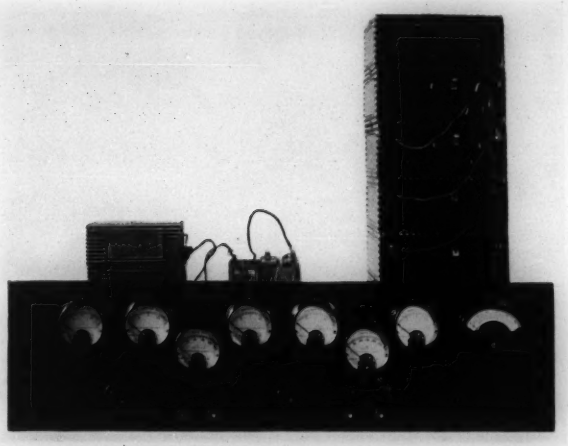
the output meters on each tube, throughout a period of several months. Occasional calibrations of the complete amplifier were also made. The calibration at the end of a period of several months was the same as the original calibration, and there has been less difficulty in maintaining it than was anticipated.

When the amplifier is connected to an oscillograph element, having a straight line calibration, the resulting combination also has a straight line calibration. The frequency and damping of the oscillograph vibrator have an important bearing on the taking of shotgun pressure records. The frequency must

be high enough to allow the element to follow the pressure variations. The vibrator element must also be damped so that it will not "overshoot" the maximum pressure, and indicate a value in excess of the true pressure. This requires close control on the temperature of the damping medium surrounding the oscillograph vibrator.

Figure 5 is a record taken while a given voltage was impressed on the input of the amplifier. This record shows

FIG. 4.



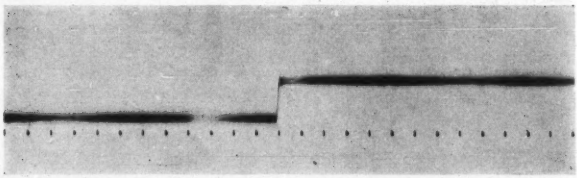
Photograph of the amplifier used to furnish the current which operates the oscillograph. The meters enable the operator to keep a check on the operation of each tube.

directly, how well the amplifier and oscillograph combination would follow a change in input voltage, and that the element was critically damped. The damping medium was oil and the temperature control was within $\pm$ 0.4° C. The small lines below the record are spaced 0.00097 second apart. As a further check on the ability of the element to accurately follow a rapid change in pressure the record shown in Fig. 6 was taken. This is a record of the pressure variation of the

fastest burning smokeless powder available, taken with two oscillograph elements simultaneously. The record with the higher deflection was the standard pressure recording element, used during all tests and calibrations, while the lower record was made by an undamped element having a natural frequency of about 13,000 cycles per second. The vertical line was drawn through the maximum pressure of the high sensitivity element at right angles to the zero pressure line. The maximum of the undamped high frequency element falls on the vertical line showing clearly that the high sensitivity element was capable of following the pressure change.

Since the gage and amplifier are, for all practical purposes, instantaneous there is no possibility of their distorting the pressure curve.

FIG. 5.

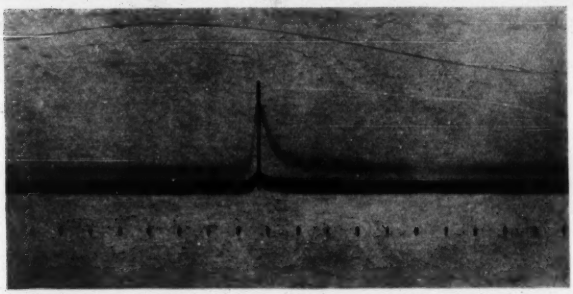


A record taken to show the ability of the oscillograph to follow current changes.

Having adjusted the amplifier and oscillograph for satisfactory operation, the calibration of the piezo-gage is the next step. This was accomplished by means of the lever system shown in Fig. 7. The gage was placed in its position with the steel hemisphere on top. The terminal which will become positive as the load is released, was placed in contact with the insulated bridge. An insulating block was placed between the lever and the loading rod which extends down to the gage. It may be added that the holes in the loading lever are reamed, and a ground, close fitting, pin was used. The load is transmitted to the gage by a lapped pin extending through a tight fitting screw plug. This insures a constant-lever multiplication of the load. With this arrangement the insulated bridge was connected to a condenser of suitable

capacity, thence to the grid of the first tube of the amplifier. The gun was connected to the other terminal of the condenser which was connected to ground. A four-megohm grid-leak was connected across the condenser to establish proper operating conditions on the first tube. After adjusting the lever until it was level, and the load was supported by the gage, the load was suddenly removed by means of a toggle. The oscillograph was deflected a definite amount proportional to the load on the gage. By varying the weight and leverage used, the gage was calibrated over the entire range of shotgun pressures.

FIG. 6.



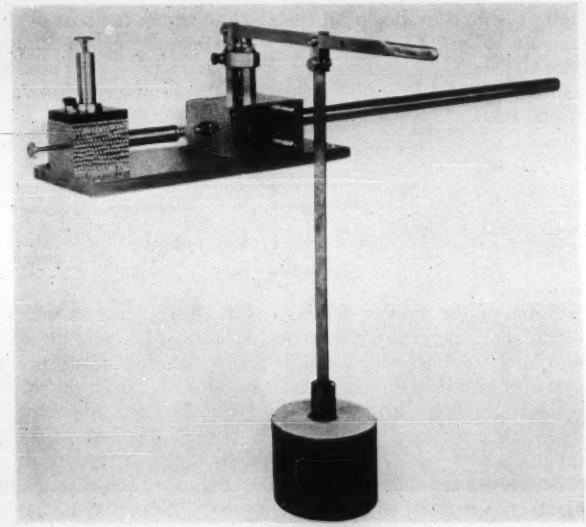
A pressure record on a fast burning powder made with a high sensitivity, damped element, and a 13,000 cycle undamped element in series. Note that both elements reach a maximum at the same time.

The load on the gage was converted to its equivalent chamber pressure and a chamber pressure-oscillograph deflection curve was plotted.

The gage has been calibrated over the entire range (0 to 15,000 pounds per square inch as it is used on this apparatus) and frequent checks prove that if the amplifier adjustment is maintained there is no change in the calibration of the entire system. Individual observations on a given point on the calibration curve check within $\pm$ 1%. A typical calibration record is shown in Fig. 8. It will be noted that the load was completely removed in considerably less than 0.001 second. The distance between two timing lines at the bottom of the

record represents 0.00097 second. The objection may be raised that the discharge of the condenser through the grid-leak will introduce an error in the record. The amount of this discharge is shown on the calibration record in Fig. 8 and it will be noted that the downward slope of the curve after the load has been removed measures about 7.25% of the maximum in 0.020 second, in this range, or about 0.36% per 0.001

FIG. 7.



Photograph of apparatus set up to calibrate the piezo-electric gage.

second. Thus, even if the maximum pressure was maintained for a full 0.001 second, the maximum distortion possible on the remaining part of the record, would be only about 0.36% of the maximum pressure, or much less than could be measured with the apparatus as it was set up. It is therefore readily seen that this effect can never introduce a serious error, in the measurement of shotgun pressures.

After having calibrated the apparatus, the lever mechanism was removed, the gage was reversed in order to have the terminal which will become positive for increasing pressure in contact with the insulated bridge, and a plug for holding the gage was placed in the bridge as shown in Figs. 1 and 2. The pressure exerted by the spring under the piston does not affect the measurement because the motion of the gage is so small that it makes any resulting change of the spring pressure negligible. Therefore, unless the spring should break, it need not be considered. After punching and inserting a shell, it is fired by means of the mechanism on the rear of the carriage. This mechanism also opens the oscillograph camera prior to firing. A standard pressure barrel (12 Gage) recommended by The Sporting Arms and Ammunition Manufacturers' Institute is used.

FIG. 8.

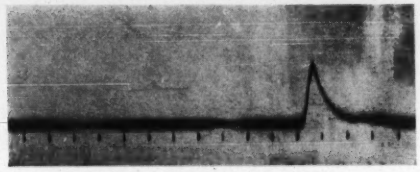
A typical calibration record.

Some of the results obtained with this apparatus will be briefly summarized. Pressure records have been made with the piezo gage, described in this article, on practically every type and brand of shotgun powder. Two records, taken on distinctly different types of powder, are shown in Figs. 9 and 10. Figure 9 is a pressure record taken on a fast burning smokeless powder. Note the rapid start and the short time which the maximum pressure lasts. Figure 10 shows a record taken on a progressively burning powder. Note that the start is slower and that the maximum pressure lasts longer. The rate of decrease is slower when a progressively burning powder is used. It may be mentioned that all of the satisfactory loads of smokeless powder, when tested, had a considerable portion on the increase side of the pressure curve as a straight line. This portion decreased, however, as deterrent was added to the powder.

Black powder produces a distinctly slower rate of increase than any satisfactory load of smokeless powder. In general

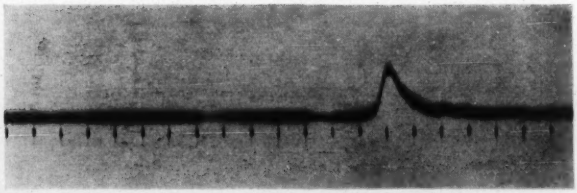
there is only a short straight line portion on the curve showing the increase of pressure when black powder is used. While it is possible to obtain a smokeless powder and primer combination with pressures even lower than those of black powder, the results are very unsatisfactory. The load will be very irregular in velocity and excessive muzzle flashes will be obtained. It is very difficult to obtain a satisfactory progressively burning smokeless powder having a maximum pressure

FIG. 9.



Pressure record on a fast burning smokeless powder. Maximum pressure = 12,200 pounds per square inch.

FIG. 10.



Pressure record on a progressive burning smokeless powder. Maximum pressure = 10,500 pounds per square inch.

less than about 9000 pounds per square inch. Maximum black powder pressures for average shotgun loads are, in general, in the range from 5000 to 5500 pounds per square inch.

If one attempts to apply the piezo gage to every type of pressure measurement, there are certain factors which must be taken into consideration. The gage, used as described in this article, while perfectly satisfactory for measurements of pressures in firearms, would not accurately indicate pres-

sures over a time interval several times as long as is here used. While it is possible to increase the size of the gage and the resistance of the grid-leak used and thereby increase the time interval during which it will accurately record pressures, there is a limit to this, imposed by the grid-filament current within the first tube of the amplifier. As a means of extending this time interval, during which the gage will accurately record a pressure, the cathode ray oscillograph could probably be very advantageously applied. Of course, there is a limit to the time interval that this combination would accurately record the pressure because of the leakage of the charge from the gage. Commercially available cathode ray oscillographs operating with the film outside of the tube, at this time, will not satisfactorily expose a trace when the film speed is greater than about 500 cm. per second. Such an oscillograph, therefore, would not be so well suited to the recording of pressures as the vibrator type, except that the leakage of the charge from the gage would be less. From data already presented it is evident that there is no reason why a cathode ray oscillograph should be used for shotgun pressure recording. It is believed, that, with only slight modifications, a piezo gage as described in this article could be used for recording pressures in all small arms, in high speed internal combustion engines, and in a large variety of instances where rapidly varying pressures are encountered.

In conclusion it may be said that the piezo-electric method of measuring shotgun pressures, and similar rapidly varying pressures, has several advantages over other methods, the principal ones being: it can be accurately calibrated, and will maintain that calibration, if simple precautions are taken; it does not have inertia factors which impair its use, and any motion of the gage is negligible.

EARLY SHIP BUILDING ON THE RIVER DELAWARE.*

BY

CHARLES LYON CHANDLER,

Manager, Foreign Department, Corn Exchange National Bank & Trust Company, Philadelphia.

I am grateful for the honor which has been paid to me by The Franklin Institute in its invitation to deliver this talk on "Early Ship Building on the River Delaware" before this old and distinguished Society and for the privilege it has given me of speaking in the Hall of the Institute which was founded to make effective the scientific ideals and policies of my forebear, Benjamin Franklin. I thank you heartily.

I have found the subject of "Early Ship Building on the River Delaware" fascinatingly interesting and intriguing for the following reasons:

First, that there was available little if any organized historical data on the subject of early shipbuilding in Pennsylvania, or, for that matter, in any other of the American colonies except Massachusetts; and, Secondly, that the subject assigned me is one which I find is indissolubly interwoven with the economic and political history of the beginning of our country in the period from My Lord Proprietor Penn to the first of your own Princeton Presidents, namely, James Madison, Princeton 1772, the fourth President of the United States of America.

I have endeavored to overcome the paucity of organized historical data on the subject for the purposes of this lecture by going back to primary sources whenever possible, and by checking the statements made by a contemporary author with such other sources, such as current newspapers, whenever available, and from original manuscripts and letters of distinguished Americans of the period. I wish to acknowledge particularly the assistance offered me by the Historical

* Presented at a meeting held Thursday evening, February 4, 1932. First delivered as the Tenth Anniversary Cyrus Fogg Brackett Lecture before Princeton University, December 8, 1931.

Society of Pennsylvania and by the Library of the University of Pennsylvania in this connection.

The character of the people comprising the colony on the Delaware founded by William Penn in 1682 distinctly differed from that of many of the other first settlements of the English in North America in the 17th century. Probably in no other group were there so many of that class of people whose absence from the early days in Virginia was so lamented by Captain John Smith, "the prudent heads of families," everyone of whom was trained to follow some definite occupation as soon as he arrived in the new world. It has often seemed to the writer as though Penn and his associates had deliberately sought out a group of people who were trained to perform almost every kind of activity that constitutes the diversified business callings needed for a growing city. We find among the first settlers virtually every trade and occupation represented, to a greater variety and extent than was the case in any of the other colonies that had been first settled. That this was the exception, rather than the rule, in English colonization may be noted from another fact that when, only a little more than 100 years later, their first settlement was made in Australia, only one person of all those that came out possessed the most rudimentary knowledge of agriculture.

It is, therefore, not surprising to find trained shipwrights and ship builders among the first people who came to Philadelphia. William West,[1, 2] who came over with William Penn, began his career by building a vessel for Penn at his shipyard near what was known as the Penny-Pot Free Landing, at the foot of Vine Street in Philadelphia. The rope walks, sail and block makers' shops, extended from just above Market Street almost continuously to this great yard of West's at Vine Street Wharf, which had been obtained by West in part payment for a vessel built for Penn. Another pioneer in this activity was Bartholomew Penrose, who came from Bristol, in England, and whose partner in these shipbuilding enterprises was William Penn. Here it should be noted that there were more settlers from the English sea-

[1] Scharff & Westcott, Vol. III, p. 2336.

[2] Moody, "Historical Outline of Shipbuilding in Philadelphia," Philadelphia, 1926.

boards among Penn's first arrivals than was the case when any of the other colonies were started.

Before going further, we must consider what was meant to be shipbuilding and what kind of ships were built in the last years of the 17th and throughout the 18th century. When ships were built of wood and propelled by sails, their possible size and proportions were limited by the nature of the structural material, while the type of structure had been evolved by long experience and was incapable of any radical modification. Stability depended principally on the amount of ballast carried.[3]

What was the shipbuilding background in 1682? The largest vessel afloat in England in 1682 was the English warship "Sovreign of the Seas," which was built at Woolwich in 1637. Her tonnage was 1,637, her keel measured 187 feet 9 inches and her main breadth 48 feet 4 inches. She was the first vessel ever built with flush decks and was pierced for 126 guns.[4]

Compare this with Columbus' ships—the *Santa Maria* was between 100 and 280 tons, and the *Pinta* and the *Nina* between 100 and 140; the *Mayflower* 180 tons; Henry Hudson's *Half Moon*, 80 tons.

"It cost Columbus $2,115 to discover America, prorated about as follows: Equipment of fleet, $900; upkeep of general staff, $105; food and wages of crew, $315; arms and ammunition, $795.

"Exactly 426 years later the inhabitants of the new land sent a military expedition to Europe costing $32,080,266,968. And the official wealth of the United States, the empire made possible by the discovery of Columbus, was set at a figure in excess of $300,000,000,000." [5]

The oak supply in England was rapidly diminishing. Pepy's notes on 4 January 1665 state that "I did my errand to Mr. Coventry about the feeling of the King's timber in the forests." The changing styles in both furniture and architecture also demanded much more oak,[6] especially with the introduction and development of the broad oak staircase.

---

[3] P. 922, Encyclopædia Brittanica, eleventh edition.

[4] Chatterton, E. Keble:—Ships and Ways of Other Days.

[5] From article by Fitzhugh Green in the New York Times.

[6] Sabine Baring-Gould, "Old Country Life," 1913 edition, page 39.

The son of Vice Admiral Sir William Penn was brought up in a shipbuilding atmosphere; Edmund Bushnell's "Complete Shipwright" was published in 1678, and the "Mariner's Jewel" by James Lightbody in 1695, both at London. The distinguished English Author Keble Chatterton, from whose valuable book "Ships and Ways of Other Days" the names of these books are taken, also informs us that the first steering wheels were introduced into ships between 1703 and 1747; previously the tiller was used for steering.

In these days when at least 300,000 of our fellow citizens think nothing of going to Europe for the summer, mostly on pleasure visits, it is very hard indeed for us to realize what it meant to travel by sea 200 years ago. As late as the time of the American Revolution people were pointed at in the streets who had gone to Europe, as though they were some strange rarity. It took William Penn three months to make the journey from Philadelphia to England, in the *Welcome* of 300 tons,[7] and even longer voyages were not uncommon. There was not merely no refrigeration, but the problem of keeping any sort of foodstuffs or supplies was always a serious, and sometimes an embarrassing, one. As late as the year 1800, the largest ship ever launched in the United States up to that period—*The Washington*, which made her maiden voyage to Montevideo in 1799, was of only 1,000 tons, and most of the ships built by Charles West or Bartholomew Penrose, or their successors, averaged about 150. Practically all the work on these vessels was performed by hand. There was not merely no machinery of any kind, but the tools used by the laborers would seem to us inefficient and crude almost beyond description. Fortunately there was always a market for ships. At a time when there were practically no light-houses or aides to navigation, the demand for ships almost always exceeded the supply. Communication between the thirteen colonies, such as existed, was nearly entirely by water, to an extent which it is impossible for us to realize nowadays. An invasion of Canada by the English, with the coöperation of the American Colonies, would be counted on to take place about once in either fifteen or twenty years, and this would

[7] Scharff & Westcott, Vol. 1, p. 87.

necessitate a large amount of shipping. Within seven years after the landing of Penn on the Delaware, Philadelphia began trading with the West Indies. This again called for more and more ships of a somewhat larger and better caliber than those employed in the Inter-Colonial trade. Such roads as existed could hardly be called roads in the modern sense of the word. We all remember Benjamin Franklin's going by water from Boston to Philadelphia in 1723. As late as the year 1800, the records of the United States, which then fitted into twelve boxes, were taken by water to the new Federal Capital at Washington from Philadelphia. Although there was always a steady demand for ships, shipping was an extremely risky business. Piracy flourished; it existed throughout the Colonial period, although it was not such a grave menace after about 1730 as it had been previously. French and Spanish privateers frequently hovered off the coast while the various European Wars were in progress, and numbers of ships that started at supposedly new ports were often captured and confiscated.

We are apt to talk today about stock exchange speculations; but the riskiest of these practices today appears safe when we consider the venturesomeness of embarking everything that one had on a vessel which might or might not come back. The profits were often large, but the danger from the total loss of the vessel would be far greater.

Even before William Penn had arrived in America, he had provided in his "Conditions Agreed upon with the Settlers" in 1681 that in clearing the land all good oak trees should be preserved for shipping,[8] and he directed his first Commission which was to lay out Philadelphia to select a site on the Delaware where "it is most navigable, dry and healthy; that is, where most ships can best ride, of deepest draught of water, if possible to load or unload at the bank or key side without boating or lightering."[9]

Within three years after William Penn had arrived at his newly founded colony of Pennsylvania (October 1685), there

[8] Cheyney, E. P., "Shipbuilding on the Delaware River," Harrisburg, 1891, a very valuable and helpful study.

[9] Myers, Albert Cook, "Narratives of Early Pennsylvania, New Jersey, Delaware." Scribners, 1912.

were shipwrights and boatwrights, ropemakers, sailmakers, and blockmakers in Philadelphia, and Penn himself expressly states that "some vessels have been here built, and many boats; and by that means (we have) a ready convenience for the passage of people and goods." [9]

Richard Norris writes in 1690 that "we have wharfs that a ship of 100 ton may lay her side to," and in that same year when Philadelphia had not more than 3,000 people, we learn from another source that there were among her comparatively few skilled mechanics, 3 master ship carpenters, 1 rope maker, making ropes for shipping, and 4 master coopers that made an abundance of casks for the sea.[9] During Penn's absence in England at this time, he ordered his sons, Springett and William, to learn shipbuilding.[10]

Eight years later, in 1698, the Philadelphia shipbuilding industry is described in greater detail by Gabriel Thomas, who states: "Now the true reason why this Fruitful country and Florishing City advance so considerably in the purchase of lands both in one and the other is their great and extended trafique and commerce both by sea and land," and who adds that "They (the inhabitants of Penn's new Colony) have curious wharfs, as also several large and fine timber yards both at Philadelphia and New Castle, especially at the metropolis (Philadelphia) before Robert Turner's Great and Famous House, where are built ships of considerable burthen," while elsewhere in his detailed narrative we learn that "they have very stately oaks to build ships with, some of which are between fifty and sixty feet long, and clear from knots, being very straight and well grain'd," and what is even more important, that "Some ships of two or three hundred tons each" had been built on Dock creek by 1698![11] Since the average English ship was less than 200 tons in 1731, 33 years later, we can gather how far Penn's colony had progressed, and Richard Castleman, writing in 1710, remarks of its chief City: "There are several coves and docks where large ships are built; and by a moderate computation, there has been

[10] Bolles, A. S., "Pennsylvania Province and State, A History from 1609 to 1790," Phila., Wanamaker, 1899, vol. 1, page

[11] Myers, *op. cit.*, p. 331; Hart, "American Hist[illegible]d by Contemporaries," Vol. II, p. 65.

launched from the stocks of this city in forty years near 300 sail ships, besides small craft, which may in some sort give us an idea of the opulancy of the place." [12]

Piracy in Philadelphia.—In the year 1697 Thomas Robinson declared that pirates walked the streets of Philadelphia in perfect safety. We have very little information—for obvious reasons—about these early Philadelphia pirates. We do know, however, that one of the goodly company of four pirates who went from the American colonies to Madagascar in 1695 was Captain John Want, a Philadelphian, who commanded the Pirate Ship Dolphin, fitted out at Whorekill, near Lewes, Delaware, from Philadelphia about 1690. Of these four pirate ships, two were from Rhode Island and only one from New York. But they were highly successful; their profits were about a million dollars apiece in our money today.[13]

The Dolphin was accidentally burned in Madagascar in 1695.[14]

On February 22, 1717, five people acknowledged themselves guilty of piracy before the Provincial Council of Pennsylvania, but were acquitted.[15]

On May 30, 1720, subscriptions were opened at the Marine Coffee House in London for the "Pennsylvania, Annapolis, Royal South and North American Society" for the importation of flax, hemp, sugar and the importing of the same with timber and deal boards, also exporting home products to those plantations, with a capital of two million pounds, and on May 17, 1720, "The Pennsylvania Society for raising hemp and flax and importing timber and deal boards" was started at the Ship Tavern in London with a capital of three million pounds. While these companies were but two among the many that tried to get established at the time of the South Sea Bubble, they serve as an indication of the direction of possibly profitable investments in the minds of business men

[12] Vol. II, page 74; Hart's "American History told by Contemporaries."

[13] Chapin, Howard M., "Privateer Ships." Captain Want captured a French ship of 120 tons and [illegible]er back to Philadelphia.

[14] Channing, "Histo[illegible]ne United States," Vol. II, pp. 264–266.

[15] Minutes of the Provincial C[illegible]ncil of Pennsylvania, Vol. III, p. 38.

in the city that was then the metropolis of the British Empire.

What would we not give for some account of what went on at the Pennsylvania Coffee House—which we know was then in existence in London—in these years of George the First? Incidentally, so far as can be ascertained no other of the English North American Colonies then had a Coffee House named for it in the capital of the Mother Country.[16]

Between 1715 and 1721 shipbuilding at Philadelphia seems to have declined, but from 1722 to 1724 it appears to have been on the increase; ten vessels of 428 tons were built in 1722; 13 of 507 tons, in 1723; and 19 of 959 tons in 1724. This growth seems to have been partly due to the removal in 1722 of the duty on lumber shipped from the Colonies to England and also to the bounty on hemp for ten years approved that year by the Pennsylvania legislature.[17] In 1705 an act of Parliament was passed granting a bounty of £4 sterling per ton on pitch and tar made in the Colonies, £6 a ton on hemp, and £1 a ton on masts, yards and bowsprits.[18]

In this connection it should be remembered that Isaac Norris (1701–1766), afterward Speaker of the Assembly, in 1734 wrote a reply to the inquiry of the Lords Commissioners of Trade and Plantations as to what encouragement was necessary to make the colonies furnish naval stores and other commodities not produced in England. It declared that hemp, pig-iron, bar-iron, being staples generally purchased with money by the subjects of Great Britain from the Northern Kingdoms might, on a bounty being given by the home government, be had from some parts of this and other colonies in exchange for the manufactures and products of the mother country.[19]

Capital rapidly accumulated in Pennsylvania during the first three quarters of the Eighteenth Century owing to its having a better balanced economic life than any other of the

[16] Scott, W. R., "Joint Stock Companies to 1720," Vol. III, pp. 451, 453.

[17] Clark, "History of Manufactures in U. S.," Vol. I. p. 20.

[18] Clark, "History of Manufactures in the United States" Vol. I, p. 24.

[19] From C. P. Keith's, "Provincial Councillors of Pennsylvania," 1733–1776, Philadelphia, 1883.

thirteen colonies.[20] Shipbuilding was partly conducted with British capital advanced in the form of goods and other mercantile credits.[19] By 1722 it was thought good policy to send over in advance the goods required to purchase timber and build vessels.[19] Soon after this the first iron furnaces were started in Pennsylvania and rendered much useful service although they did not improve much technically in the Colonial period.[21] Before the Revolutionary War more than a third of the tonnage afloat under the British flag had been launched from American dockyards. An oak vessel could be built at Gloucester or salem for $24 a ton. Nowhere in England, France or Holland could a ship be made of oak for less than $60 a ton.[22]

Between 1727 and 1766 seven hundred and thirty-seven ships were built in Philadelphia,[23] and 45 between 1769 and 1772. So far as can be ascertained and inferred from available statistics it appears probable that between 850 and 900 ships had been built in Philadelphia during the 93 years from William Penn's landing to the outbreak of the Revolutionary War, more than in any other of the English Colonies in North America.[24] At least 160 were constructed there from 1781 to 1787 inclusive [24]—between one-fifth and one-sixth of those built during the previously mentioned period of 93 years.

Timothy Pitkin (Statistics, p. 345), writing in 1817, estimated that, as far as Pennsylvania was concerned, three-eighths of her registered tonnage in 1770 was owned by native Pennsylvania merchants; another three-eighths by British merchants occasionally resident in the colonies; and the remaining two-eighths by British merchants resident in Europe. Some of these latter seem to have lived in the Netherlands and Portugal, as will be seen from what follows.

---

[20] Clark, Victor S., "Economic History of the U. S.," Vol. 1, p. 146.

[21] Peters, Richard, Two Centuries of Iron Smelting in Pennsylvania," *Chester, Pa., Times Press*, 1920.

[22] John Fiske, "The Critical Period of Amer. History," p. 142 (1898 Edition).

[23] Harlow's "Growth of the United States," p. 100; see also *Pennsylvania Magazine of History and Biography*, Vols. 23–28 inclusive.

[24] From "Historical Outline of Shipbuilding in Philadelphia," by Lewis F. Moody, of the William Cramp & Sons Ship and Engine Building Company of Philadelphia.

A number of the ships built at Philadelphia from 1727 to 1776 were owned by others than Philadelphians or Pennsylvanians. As early as 1727 we find a snow called the *Ann and Elizabeth*, which was 60 tons, owned by John Delapierre and Elizabeth Freeman, both of Jamica.

In the year 1730, we hear of a Philadelphia built ship called the *James*, of 80 tons, which was owned by five people "all of Glasgow in North Britain." Another Philadelphia snow, of which mention is made in the year 1731, was owned by eight different people in Bristol, England, and in the same year a ship of 150 tons called *Longford*, was built for Richard Ferrall of the island of Barbados. Four years before this a Philadelphia built sloop called *James*, of 30 tons, is mentioned as having been partly owned by Barbados people.

In 1739 the ship *Happy Return* of 60 tons was owned by William Kirkpatrick of Londonderry, Ireland, and by Hugh White and Robert Finley of Dublin, Ireland, and by William Harper of Philadelphia. In 1743 we learn of a Philadelphia built ship called *Westmoreland*, of 200 tons, owned by John Dodd Bonell of London, England. This seems to have been one of the largest ships built in Philadelphia up to that time.

At least two English merchants were so pleased with a Philadelphia built ship that they owned, that they bought another. These were Martin Rockliff and Lawrence Williams. Apparently in the year 1742, when they are described as owning the *Shippen* of 110 tons, they were both residing in Lisbon, Portugal. They appear as joint owners of the *Shippen* with William Till and William Labourn, who were apparently both Philadelphians. Two years later Rockliff and Williams appear as the sole owners of another Philadelphia owned ship called *Martha*.

In 1742 William Wilson of Philadelphia and Edward Rivet of London appear as owners of the ship *Phoenix* of 200 tons, said to have been the largest built in Philadelphia up to that time. In 1752 we find a Philadelphia built vessel called *Barclay*, which was owned by John Brown and John Stedman, who are described as British merchants residing at Rotterdam. In the same year, we learn of a Philadelphia built snow called the *James and Christopher*, whose owners were Thomas Power of Waterford, Ireland, and John White, a British merchant

residing at Lisbon, Portugal. Thomas Power was not the only Irishman who owned a Philadelphia built ship in 1752. Captain Morgan Mulloney was part owner and also captain of a Philadelphia built snow called the *Charming Jenny* of 90 tons. The rest of her was owned by Messrs. John Ayney & Company, who were described as British merchants residing at Lisbon. In 1752 we also learn of the ship *Jane* of 80 tons, which was owned by William Kelley of Philadelphia, John Mayne of London and Edward Burne and Charles Mayne of Lisbon, Portugal. An early Quaker contact in the ownership of vessels is found in this same year, 1752, in the Philadelphia built ship *Lucy*, which was owned by Edward Pennington of Philadelphia and John and Henry Gurney of Norwich, England.

Another Portuguese contact is in 1761, the Philadelphia built ship the *Betsey and Sally*, having been owned in that year by Richard Neave of London, Messrs. Thomas and John Lampriere, British subjects residing at Faro, Portugal, and also by Samuel Wharton and John Baynton of Philadelphia. John Baynton was also part owner in the Philadelphia built brigantine Lucia in 1764, his co-owners being Messrs. Walter Staple and Skelhorn, merchants in the island of Jamaica, and Samuel Wharton and George Morgan, Philadelphia merchants. The ship *Mermaid* was owned in 1765 by Messrs. Richard Brew and William Webster of Anamoboa, in Africa, and Samuel Smith of London. She was a large vessel for that time, of 130 tons.

There seems to have been a slight increase in the ownership of Philadelphia vessels by foreigners during the last six years, when Pennsylvania was still a part of the British dominions. In 1770 we find the Philadelphia built ship *King of Portugal* of 120 tons, captain, Richard Buckley, owned by Richard Dennis and Richard Buckley, and Messrs. Parr and Buckley of Lisbon. In the same year, Messrs. James Crawford & Co., British merchants residing at Rotterdam, Netherlands, and Robert Morris and Thomas Willing of Philadelphia, owned a ship called the *Minerva*, which was built at Newburyport, Mass.

In 1773 the Philadelphia built sloop *Richard* of 150 tons, was owned by John Postelthwaite and John Benson of Liver-

pool and by Andrew Caldwell and Joseph Wilson of Philadelphia. Richard Caldwell of Londonderry is listed as the owner of the Philadelphia built, 160 tons ship *America*, in that year. William Willock and Arthur Morson, both of the Island of Antigua, owned the Philadelphia built ship *James and Rebecca* of 120 tons, in 1773, and in that same year Robert Threlfal and David Anderson both of the island of Grenada, are listed as owners of the 20 ton Philadelphia built sloop *Sally*.

So far as the writer has been able to ascertain, the largest vessel built in Philadelphia before the American Revolution was the ship *Delaware*, of 300 tons, which is listed in 1773 as belonging to Moses Franks of London and David Franks, who was apparently then living in Philadelphia.[25]

We fortunately have figures showing and classifying shipbuilding in Philadelphia during the three years for 1769, 1770, 1771, as follows:

	Square Rigged Vessels.	Schooners and Sloops.	Total.
1769.....	14	8	22
1770.....	8	8	16
1771.....	15	6	21

In the year from January 5, 1770, to January 5, 1771, there entered into Pennsylvania ports vessels of 50,901 tonnage, while vessels of 49,654 tonnage cleared therefrom;[26] only Massachusetts showed a greater number of entrances and clearances that year; Virginia coming directly after Pennsylvania.

Of the 182 vessels built in the American Colonies in 1772, with an aggregate tonnage 26,544, only 8 were built in Pennsylvania; all at Philadelphia.[27]

We are extremely fortunate in possessing a manuscript book in the Pennsylvania Historical Society, the Shipyard

[25] The above is derived from a series of articles entitled "Ship Registers for the Port of Philadelphia, 1726–1775," published in Vols. 23–28 inclusive of the *Pennsylvania Magazine of History and Biography*. They begin on Page 254 of Vol. 23 thereof.

[26] Pitkin, Timothy, "A Statistical View of the Commerce of the United States of America," New Haven, 1835, page 346.

[27] Cheyney, "Shipbuilding on the Delaware River," Harrisburg, 1891.

Accounts of Wharton and Humphreys from 1773 to 1795, whence much valuable data on shipbuilding in Philadelphia has been obtained for this work. We can also gather therefrom at least a partial list of the ships built in Philadelphia in 1774 and 1775, since Wharton and Humphreys were constantly engaged in not merely building ships themselves, but in supplying material to other ships built in Philadelphia. Wharton and Humphreys had bought out Wharton and Grice for £615 on January 1, 1774. We are therefore able to compile from this book the following statement of the names of the vessels built in Philadelphia in 1774 and 1775. The dates of the months in the following table are those at which Wharton and Humphreys supplied materials for, or rendered a bill for the construction of, the vessels in question:

1774.

Date.	Owner.	Type.	Name.
1. February 14, 1774	Stocker and Wharton	Brig	Ranger
2. March 4, 1774	Stocker and Wharton	Schooner	Industry
3.	Andrew Caldwell	Brig	Boscawen
4. October 19, 1774	Conyngham and Nesbitt	Schooner	Kingston
5. June 22, 1774	Conyngham and Nesbitt	Ship	George
6. June 22, 1774	Michael Connor	Sloop	Rebecca
7.	Stocker and Wharton	Ship	Peggy and Sally
8.	Mease and Caldwell	Brig	Tobago
9.	Willing, Morris & Co.	Brig	George
9a.	Budden and Straker	Brig	Harriott
10. December 31, 1774	Robert Ritchie	Sloop	Maria
11. December 31, 1774	Andrew Caldwell	Ship	Jupiter
11a.	Mease and Caldwell	Ship	Richard Penn
12.	Conyngham and Nesbitt	(?)	Sally
13. October 19, 1774	Andrew Caldwell	Ship	Delaware
14. December 31, 1774	Robert Ritchie	Ship	Liberty
15. October 19, 1774	Willing and Morris	Ship	Black
16. October 1, 1774	Stocker and Wharton	Brig	Harmony
17. July 22, 1774	Isaac Wharton	Schooner	Thames
18. August 15, 1774	Stocker and Wharton	Ship	Butcomb

We learned from these books that in 1774 and 1775 nine shillings a day was paid to a laborer for work in the Wharton and Humphreys shipyard. Some idea of the materials used in the ship can be seen from the bill submitted to Conyngham and Nesbitt for the ship *George* on March 12, 1774. Fourteen men were employed in constructing this vessel and in the construction of it there were used 1,600 feet of sheaving

boards, 6 red cedar staunchions, 2 red cedar timber heads, 1 crutch, 2 anchor stocks and trenels, 1 knee on the bowsprit, and for caulking her, 30 bushels of hair and 92½ bushels of oakum were applied by means of three pots and ladles.

When the sloop *Rebecca* was made for Michael Connor, 2 "breaming tubbs," together with 4 poles and 2 mops were employed, as well as "3 potts and a ladle," presumably for the caulking.

From the frequency with which certain names are repeated among the workmen, it is apparent that there must have been a number of them engaged in the sole occupation of repairing and building ships. For instance, Thomas Bulkeley's name repeatedly occurs among the laborers. In one or two instances, "boys" were also employed, who were probably apprentices in the shipbuilding trade.

1775.

Date.	Owner.	Type.	Name.
Feb. 20	Stocker and Wharton	Snow	Prudent Sally
" 23	Capt. John Mallowny	Brig	Catherine
Jan. 14	Conyngham and Nesbitt	Schr.	Betsy cost £71
" 17	John Nixon	Ship	Commerce
Mar. 29	Stocker and Wharton	"	Nancy & Polly
" 29	" " "	Snow	Salter
May 4	Michael Connor	Brig	Rebecca—cost: £374—15 workmen employed at 9/ a day each
May 22	Capt. Smith	Schr.	Loyde
May 31	Thos. and Isaac Wharton	Sloop	Betsey
June 23	Stocker and Wharton	Sloop	Unnamed
" 26	Thos. and Isaac Wharton	Brig	Hannah
" 29	Peter Land	Sloop	Lady Catherine
May 4	John Nixon	Ship	Black Prince
July 10	Stocker and Wharton	"	Barbados Packet —cost: £147—21 men employed
Aug. 5, 1775	The Committee of Safety	Boat	Experiment—cost: £273.8.5
May 8, 1775	Willing and Taylor	Brig	Morning Star
Aug. 30	Benjamin Gibbs	Ship	Matilda
June 7	Willing and Morris	Brig	George—cost: £86

Arthur Donaldson in 1774 invented the first American Dredging Machine, for which on February 22, 1775, the

Committee of the Pennsylvania Assembly awarded him £100. The Assembly said in the accompanying Resolution that "Many of the docks in this city are now totally deserted to ships of burthen, merely from the impracticability of loading there, and the evil is becoming very general; for extending wharves into the channel is but a temporary remedy, the eddy which sets into the docks continually depositing mud. If once this machine could but be brought into general use, the dock owner might enjoy the full benefit of his property and the merchant might be more conveniently accommodated."

I am indebted to Mr. B. Hoff Knight for the above reference.

The occupation of Philadelphia by the British from 1777 to 1778 put a stop to the ship building activities which had been especially marked from 1775 to 1777, when Joshua Humphreys built there some of the first vessels for the United States Navy,—the "General Washington," cost £355; with £85 for decking it: the Alfred, £360.[28] Before leaving what might be termed the Colonial period of Philadelphia shipbuilding, it should be noted that shipbuilding was carried on much more economically in the American Colonies than in Great Britain.[29]

Some idea of the way in which Philadelphia was regarded as a ship building center at the outbreak of the American Revolution can be gathered from the fact that the Committee appointed by the Continental Congress under their order of December 11, 1775 "To devise ways and means for furnishing these Colonies with a naval armament" reported on December 13, 1775, that more of the 13 ships they had determined to build were to be constructed in Pennsylvania than in any other state—Four, as compared with two each in Massachusetts, Rhode Island, and New York, and one in New Hampshire, Connecticut and Maryland. These vessels were to cost not more than $66,666.00 apiece. It may be noted that there was then not a single Philadelphian or Pennsylvanian on this Naval Committee. All the gun powder and small arms for the vessels secured by the Committee was furnished by the Committee of Safety of Pennsylvania.

[28] Humphreys mss., Pennsylvania Historical Society.

[29] Pitkin, "Statistics of the United States," 1835, p. 346.

The first of these four ships to be completed was the Randolph, commanded by Nicholas Biddle; the second was the Delaware, Captain Alexander, and another was the Effingham which was afterward taken up the Delaware River and sunk by Commodore John Barry at White Hill, N. J., to prevent her capture by the British.

The contemporary historian, David Ramsay, states that "at the time (June 1775) that the Colonies adopted these spirited resolutions they possessed not a single ship of war, nor so much as an armed vessel of any kind." As we have already mentioned, it is difficult to imagine how such vessels could have been prepared or procured had shipbuilding not become such an established industry in Philadelphia and other sea-ports.[30]

On December 21, 1776, Robert Morris wrote that ships that were considered worth a thousand pounds twelve months ago, now sell for three thousand or upwards. Morris complains that "Every article belonging to shipping is excessively dear" and particularly emphasizes "the lack of sea coal for our anchoring." [31] Wharton and Humphreys paid from 7 to 9 pence a day wages in 1774; in 1781, 10, and 1782, 12 shillings.[32]

Such statements show how much American industry has advanced. Imagine any industry complaining in Philadelphia in 1931 of the lack of coal. It will, therefore, be seen that the Rhapsody of Timothy Dwight, President of Yale College, which was written by him in 1777, may be considered as slightly premature regarding naval preparations:

> "Thy fleets to all regions thy Power shall display,
> The nations admire, and the ocean obey,
> Each share to thy glory its tribute unfold,
> And the East and the South yield their spices and gold." [33]

We know something of the technical literature of the times: It seems probable that British works on shipbuilding were widely consulted by these early shipbuilders in the

---

[30] David Ramsay, "History of the U. S.," Vol. II, p. 15.

[31] Hart, "American History told by Contemporaries," Vol. II, pp. 556–558.

[32] For Humphreys, see also Moody, *op. cit.* Humphreys mss., Pennsylvania Historical Society.

[33] Hart, A. B., Vol. II. p. 466, "American History told by Contemporaries."

Colonies and in Pennsylvania. There are still in good state of preservation two text books on the art of shipbuilding and of naval architecture that show evidence of daily use in the Penrose Shipyards at Philadelphia, from about 1781 to 1813 and later. I have had access to these large volumes and find in them frequent pencil notations in the handwriting of Charles Penrose (1776–1849), shipbuilder, Director of the Bank of Pennsylvania, a Port Warden of Philadelphia, and intimate friend of William Jones, Esq., Secretary of the Navy. Not only are there many pencil entries (recognized from similarity to his signature on the fly leaf) but shipbuilding sketches and diagrams with lettering in the same hand.

Both volumes are picturesquely quaint in treatment of the subject, and both were published in London—one in 1781 (a second edition) and the other in 1805.

Published in 1781 and dedicated to "King George III's Most Excellent Majesty," the volume: "*Naval Architecture or the Rudiments and Rules of Ship Building*" by Marmaduke Stalkartt, is divided into seven books, respectively: "Of Whole Moulding"; "Of the Yacht"; "Of the Sloop"; "Of the Forty-Four-Gun Ship"; "Of the Seventy-Four-Gun Ship"; "Of the Cutter, and Ending of the Lines"; and by requests to the Author, "Of the Frigate."

The other volume published in London "at the Navigation Warehouse, Little Tower Hill," in 1805 in the midst of the Napoleonic wars, is entitled "*The Elements and Practice of Naval Architecture*" by one David Steel, and has this characteristically modest and unfortunately inaccurate British prelude to the preface:

"In the navy of Brittania consists her strength, her greatness and her glory; it may therefore seem remarkable that we have never yet had, in the English language, a treatise on Naval Architecture, calculated to convey, to her sons, a general knowledge of the science; especially, as such a treatise has long been a desideratum in the British Islands."

The language of the book, in expounding the truths of ship design, in terms of "a series of Thirty-Eight Large Draughts, and numerous smaller engravings," is not without the glamour of early 19th Century phraseology! On page 137, we read:

"Let the midship section, *figure 2*, in *plate H*, be referred to in elucidation of this case. If the centre of gravity be placed at D, it will enable the vessel to preserve a situation completely upright, notwithstanding a resistance against the side FQ. But, if the centre of gravity be raised too high, as to E, the resistance on the same side, FQ, acts in conjunction with the wind, and contributes with all its force to raise the windward side FQ out of its position; thus the vessel becomes crank and unsafe."

All of this in 1805, with sail still supreme and steam navigation yet unborn!

I rejoiced to unearth in a footnote to page 161 of this British authority on shipbuilding, this gem from the inventive and versatile mind of the first United States Minister to the Court of Versailles, who had died fifteen years earlier, and to honor whose memory the French Assembly went into mourning for three days:

"The illustrious Dr. Benjamin Franklin, in a letter to Alphonsus Le Roy, published in the second volume of the *American Philosophical Transactions*, noticed a plan for dividing vessels into compartments rendered water-tight, upon a principle similar to that recommended by Captain Schank, in the following words. 'While on this topic of sinking, we cannot help recollecting the well-known practice of the Chinese, to divide the hold of a great ship into a number of separate chambers, by partitions tightly caulked, of which you gave a model in your boat upon the Seine; so that if a leak should spring in one of them, the others are not affected by it; and, though the chamber should fill to a level with the sea, it would not be sufficient to sink the vessel. We have not imitated this practice; some little disadvantage it might occasion in the stowage is perhaps one reason, though that I think might be more than compensated by an abatement in the insurance that would be reasonable, and by a higher price taken of passengers, who would rather prefer going in such a vessel. But our seafaring people are brave, despise danger, and reject such precautions of safety;—being cowards only in one sense,—*that of fearing to be afraid.*'"

The embargo laws which forbade exportation were re-

pealed by Congress 27 February 1781 as being mischievous to Pennsylvania.[34]

The following tables indicate the development of ship-building in Philadelphia from 1781 to 1787:

	Number.	Tonnage.
1781	7	1,120
1782	22	2,146
1783	40	4,477
1784	44	5,303
1785	20	2,412
1786	13	905
1787	16	1,644

The forty vessels built in Philadelphia in 1783 may be classified as follows:

13 Ships and Barks	2,943	Tons
15 Brigs	1,243	"
4 Schooners	91	"
8 Sloops	200	"

The largest were the Ships:

Alliance	700	"
Thomson	300	"
Pigou	300	"

By a law passed by the State of Pennsylvania in 1787, a reduction of 5 per cent. from the import duties was allowed on goods imported in vessels built in Pennsylvania and at least two-thirds owned by citizens of that State.[35]

On the Fourth of July, 1788, a great parade to commemorate the establishment of the Federal Union was held in Philadelphia. A model of the Federal Ship Union was exhibited; she was followed in the parade by delegations representing

1. Pilots of the Port
2. Marine Society
3. Boat Builders
4. Sail Makers
5. Ship Carpenters, headed by Manuel Eyre
6. Ship Joiners
7. Rope Makers
8. Ship Chandlers [36]

---

[34] William Graham Sumner: "The Financier and Finances of the American Revolution."

[35] Johnson, p. 138.

[36] See The Pennsylvania Packet and Daily Advertiser Issue of July 4, 1788

Since business in Philadelphia gradually improved from 1786 to 1789,[37] more and more capital went into ship building, which was further aided by the third act of the first Congress of the United States, adopted July 20, 1789, imposing tonnage duties discriminating in favor of United States Ships.[38] This was largely enacted to help United States shipbuilders. These duties were as follows: On vessels built and owned in America and on foreign-built vessels owned by Americans, on or after May 29, 1789, six cents; on vessels thereafter built in the United States, but partly or wholly owned by foreigners, thirty cents. All merchandise imported in other than U. S. ships paid an extra tariff of 10 per cent. by the Tariff Act of 1794;[39] on all other vessels, fifty cents. These discriminating tonnage duties were continued by the tariff act of March 27, 1804, which doubled the previous tonnage tax levied on foreign vessels and placed a new duty, known as "light money," amounting to fifty cents per ton, on all foreign ships entering the ports of the United States. Foreign shipping was thus placed at an even more serious disadvantage than before as a result of this legislation. The United States not merely was able to carry 92 per cent. of its imports and 88 per cent. of its exports in its own vessels, but had a surplus of vessels for export, selling 'ships amounting to hundreds of thousands of tons' to foreigners (Bates, p. 424).[40] These legislative advantages began to be abolished in 1815, but during the 28 years of their enforcement who can tell to what extent they affected the economic growth of the United States and more especially Philadelphia, the largest city and seaport in the United States—according to the censuses of 1790 and 1800, when it had 42,450 and 69,403 people respectively.

At this point it is interesting to note the contemporary opinion of Tench Coxe, perhaps the foremost United States economist of his time. Coxe was personally interested in ship building and other business ventures. He also had

[37] Coxe, p. 76—"Shipbuilding has made a corresponding progress between 1786 and 1792."

[38] Johnson, p. 296.

[39] Bates, William W., "The American Merchant Marine," New York, 1891.

[40] Bates, William W., "The American Merchant Marine," New York, 1891.

charge of large portions of the first three censuses of the United States and was probably as well informed on its industries as any other contemporary. The following passage was written in the year 1790 and is taken from his book entitled: A View of the United States of America, in a series of papers written at various times between the years 1787 and 1794. Philadelphia, 1794, Pages 71–73.

"Shipbuilding is a business in which the port of Philadelphia exceeds most parts of the world. Masts, spars, timber and plank, not only from our own State and the other states on the Delaware, are constantly for sale in our market; but the mulberry of the Chesapeake and the evergreen or live oak, and red cedar of the Carolinas and Georgia, are so abundantly imported that nine tenths of our vessels are built of them. No vessels are better than these; and in proof of it, English writers of rank might be quoted who have published for and against us. A live oak and cedar ship of 200 tons carpenter's measurement, can be fitted to take in a cargo for £14 currency a ton, and there is not a port in Europe in which (A.D. 1790) an oak ship can be equally well built and fitted for twenty pounds per ton in our money, or £12 sterling. This fact may appear doubtful or extraordinary; but it is certainly true; and it is greatly in favour of our ship carpenters and other tradesmen employed in fitting ships; as well as our merchants and farmers, whose interests are so much connected with navigation.

"The distance of Philadelphia from the sea, has been made an objection by some, and the closing of our river by the ice, which happens almost every winter. Amsterdam, the greatest port in Europe, is inaccessible in the winter. But it is a fact, that, notwithstanding these objections, our vessels make as many West India voyages as those of the two other principal sea ports of the Middle States, and though the river is frozen from three to nine weeks almost every winter, yet there are occasional openings which give opportunities for fleets of merchantmen to go out and come in. The fine corn and provision country, which lies near Philadelphia, enables the merchants to load their vessels in the winter; and the market is regularly supplied with flour, pork, beef, lumber, staves, iron, and many other of our principal articles of exportation.

"Little time is therefore lost; and we find that our trade increases. The crop of 1789 and other exports from the harvest of that year to that of 1790, it is supposed, will load 120,000 tons of shipping. We have a very extensive back country; and many large bodies of new land, which must send their produce to the Philadelphia market, are settling fast. The population of Pennsylvania . . . proved to be 434,000 by the census of 1791."

I will now show you a photograph of a model of a Philadelphia-built ship of the 18th century, the *Canton*, which made the first voyage from Philadelphia to China and India, thus opening the Oriental trade of this port. She sailed December 30, 1785, with a cargo of 41 hogsheads and 226 barrels of ginseng and 3 rolls of lead and returned May, 1787, with a fine cargo of silks, teas and Indian goods. She sailed on her second voyage December 6, 1787; and several larger ships were placed on this trade soon after.

The Canton was commanded by Thomas Truxtun, and was owned by John Donaldson, William Coxe, Nalbro Frazer, John Pringle, and Thomas Truxtun. Length, 96 feet; breadth, 25 feet; depth, 13 feet. Tonnage 250.

Some idea of the size and type of vessels built in Philadelphia at this time may be gathered from the advertisements in contemporary Philadelphia newspapers. A ship called the Caesar was built at Philadelphia in 1789 of a live oak and cedar frame, 69 feet 9 inches keel, 26 feet beam, 13 feet hold, of 249 tons, said to carry 14,000 bushels of grain.[41]

The ship General Washington of live oak and cedar frame, was built in Philadelphia in 1791, 74 feet keel, 25 feet beam, 12 feet hold, "a strong firm built vessel," burthen 155 tons.[42] We have the measurements of two vessels built in Philadelphia in 1793—the big *Flora* of white oak frame (but her principal timbers were of live oak), of 116 tons,[43] and the big *Fair American* of live oak and cedar frame, burthen 94 tons,

[41] Samuel Smith's Advertisement, Issue May 27, 1797, Claypoole's *American Daily Advertiser*.

[42] "General Washington" Advertisement, Issue June 3, 1797, Claypoole's *American Daily Advertiser*.

[43] "Flora" Advertisement, Issue July 25, 1797, Claypoole's *American Daily Advertiser*.

completely fitted, sails fast and is said to carry 1,000 barrels. Her keel measured 54 feet, her beam 20 feet 6 inches and her hold 8 feet 1 inch.[44]

The rules of the New York Chamber of Commerce in 1797 stated that a ton was to consist of 8 barrels of flour, and 6 barrels of beef, pork, tallow, pickled fish, pitch, tar and turpentine; thus the sloop Polly which Manuel Eyre had for sale in Kensington, Philadelphia, on July 20, 1797, whose burthen was about 600 barrels, probably was of about 75 tons.[45] A Philadelphia built schooner named the *President*, of live oak and cedar frame, was advertised for sale in Claypoole's *American Daily Advertiser* for May 26, 1797; her burthen was 92 tons, to carry 800 barrels.

The largest ship brokerage business in Philadelphia at that time was that of Samuel Smith, at 86 Front Street, below Market. He was an early Philadelphia booster; he advertised as follows in the issue of Claypoole's *American Daily Advertiser* for October 12, 1797: "The port of Philadelphia, from its extent, its industry and its opulence, may be considered as the commercial metropolis of the United States."

So far as can be ascertained, 635 vessels were built in the United States in 1798—tonnage being 49,435. The Sally, mentioned in the above, was finished in December, 1774—of 287 tons, 75 feet keel and 27 feet beam. She cost £1870.8.6,[46] and was largely built of pine and oak.

One of the most prominent shipbuilders of this period was Samuel Bowers who, was born at Southwark in 1760, and began shipbuilding at Kensington in 1789. In 1790 he received $2,940.67 for a ship and $1,288.66 for a brig—and did some $2,000 worth of repairs. In 1790 he did a business of about $15,000.

In 1796 he built the Samuel Smith of 705 tons for $24,000.

In 1795 he built the Indostan of 470 tons for the East Indian trade at $31.00 a ton.

For several years a ship for the China and East Indian trade was launched at Bowers' yard each year.

---

[44] "Fair American" Advertisement, Issue June 2, 1797, Claypoole's *American Daily Advertiser*.

[45] Claypoole's *American Daily Advertiser*, July 20, 1797.

[46] Johnson, p. 125.

After 1816 he built several steamboats for use on the Delaware and other rivers. He once completed a brig of 200 tons in 6 weeks.[47]

Now let us turn for a few minutes from economic to political history. Suppose there had been no shipbuilding industry in the Thirteen Colonies in 1775. Suppose Governor Winthrop had never built the Blessing of the Bay near Boston in 1631 and Bartholomew Penrose had never constructed the "Diligent" at Philadelphia in 1707. What would have happened if the Colonies had possessed, not merely no shipbuilders, but no shipbuilding inheritances and traditions?

Would the Colonies have been as readily united as they were? And, furthermore, would they have had any navy, or means of creating one, had their shipbuilding not constantly developed?[48]

We should never forget that by 1775 shipbuilding had become a hereditary profession in Philadelphia. For nearly a century and a half four generations of shipbuilders named Penrose were among the most prominent in their professions in Philadelphia. The first of these was Bartholomew Penrose, who was baptized in St. Stephen's Parish in the City of Bristol, England, on January 21, 1674, and who was buried in Christ Church Cemetery, Philadelphia, on the 17th of November, 1711. Soon after arriving in Philadelphia, about the year 1700, he established a ship yard, in the development of which he is shown to have been financially assisted by both William Penn, and William Penn, Jr., and by James Logan. In the winter of 1706 he built the 150-ton ship *Diligence*, which was launched in Philadelphia on May 4, 1707. His shipyard was at or near the corner of Delaware Avenue and Market Street. His son Thomas was born some time in the winter of the year 1709–10, and died in Philadelphia on the 17th of November, Seventeen Hundred and Fifty-Seven. His grandson Thomas was born on January 22, 1733, and died on the 28th of November, 1815. He had many dealings with Wharton and Humphreys in 1774, furnishing them with supplies for their vessels, and his great grandson Charles

[47] Cheyney, "Early Shipbuilding on the Delaware River," Harrisburg, 1891.
[48] Clark, "Industrial History of the U. S.," Vol. I, p. 29.

(14 September 1776–24 June 1849) was asked by President Madison, a Princeton graduate, in 1812 to supervise the construction of the Man-of-War Franklin, long believed to be the best built ship of her class in the United States or any other Navy.[49] Another member of this family, Samuel Penrose, was one of the Committee of Four—David Thomson, Francis Grice and William Pollard being the others—who accepted a large amount of material for shipbuilding which covers nearly three pages in the Wharton-Humphreys account book, on behalf of the Continental Congress for the vessels then being built for them on January 5, 1776.

We must remember that Thomas Penrose, the second, had actually built a warship at Philadelphia in 1762, which attacked the Spanish West Indian colonies. Had England been engaged in any prolonged conflict with other European powers about 1770, it is probable that many other warships would have been constructed in the Colonies, whose sailors were already known in international trade.

So the one colonial industry that had been sedulously fostered and encouraged by England proved to be the chief means by which the Colonies became sufficiently closely knit together to oppose her when the occasion arose. The interaction of economic on political history has seldom been more clearly illustrated.

It will be remembered that when the American Colonies of Spain and Portugal declared their independence, and struggled for it from 1810 to 1826, they had no shipbuilding industries of their own. They were forced to rely entirely on the shipping of foreign countries, mostly on those of the United States, for vessels with which not merely to trade with Europe but to trade with each other. After the capital of the Portuguese-Brazilian Kingdom was moved to Rio de Janeiro in 1808, that Government had to employ Philadelphia-made vessels to communicate with its African and Indian possessions.

What caused the industrial development of the United States from 1789 onward?

[49] All the above statements regarding the Penrose family are taken from "The History of the Penrose Family" by Josiah Granville Leach, Philadelphia, 1903.

No statistics have been found regarding shipbuilding at Philadelphia from 1787 until 1793; between March 1 and June 29, 1793, twenty-six vessels were built measuring 4,618 tons; and in the 18 months from January 1793 to June 30, 1794, the tonnage built amounted to 10,204 tons.

In 1795, 31 vessels were built, and in 1796, 22. From March 1 to June 29, 1793: 9 ships—2,462 Tons; 9 brigs—1,542 Tons; 3 schooners, 244 Tons; 5 sloops, 270 Tons.

Stephen Girard's vessels were built about this time—the *Sally*, whose 153½ tons were made of mulberry, red cedar and locust wood, all of which was obtained in and near Philadelphia, launched in 1794; and the *Liberty*, 259 tons, built at Kensington, in what was then called the *Northern Liberties*, in 1795; on December 5, 1795, Girard's good 305-ton ship *Voltaire* was launched, built of live oak and cedar, while the *Rousseau* of 300, the *Good Friends* of 246, and the *Montesquieu* of 372 tons first entered the waters of the Delaware at about the same time. The *Nancy*, of between 93 and 94 tons, though smaller, was also a credit to Philadelphia shipyards and performed many long ocean voyages.[50]

One of the six frigates authorized by Congress in 1793 was the 44 gun frigate *United States*, of 1,576 tons, costing $299,336, which was launched at Philadelphia July 10, 1797, being the first of the six to be completed. She was designed by Joshua Humphreys, of Philadelphia.[51]

Philadelphia shipbuilding between 1783 and 1812 is acknowledged to have excelled any other south of New England, and larger vessels were built in Philadelphia than in New England.

The oak and other woods along the Delaware were admirable in quality and abundant in quantity. The live oak was brought to Philadelphia from the South.

The shipyards stretched along the river front at Kensington and Southwark—as many as 12 or 15 were operating at one time. In the year 1801 fourteen were actively engaged.[52] A master shipbuilders' society flourished, and not only were

[50] McMaster, "Life of Stephen Girard," Volume 1, pp. 329, 335, 280, 313, 302, 411, 405.

[51] Maclay's "History of the United States Navy," Vol. I, pp. 158–159.

[52] Moody, *op. cit.*

vessels built here for both foreign and domestic orders, but Samuel Bowers, a Kensington shipbuilder, whom we have already mentioned, was asked in 1800 to become the chief naval constructor of the Spanish Government and Samuel Humphreys (son of the Joshua above referred to), received a similar offer from Russia.

No less than eighty-seven times during the first six months of the year 1800, the following advertisement was printed in the Philadelphia Journal Advertiser, which casts light on the way in which shipbuilding was then regarded. The advertisement is that of a book on the English Constitution—which is described as "the most stupendous fabric of human invention." The following statement, attributed to President John Adams, is quoted in the advertisement: "not the formation of languages, *not the whole art of navigation and shipbuilding*, does more honour the human understanding than this system of government."

The Rebecca Sims sailed from Capes of the Delaware to London in 14 days in 1807. The Woodrop Sims was built in 1801 of over 500 tons. In the period 1800–1812 the cost of building vessels at Philadelphia varied from $20.00 to $36.00 a registered ton.

According to a digest of facts of 1810 by Tench Coxe there were 13,100 tons of shipping valued at $992,500 built in Philadelphia county in 1810. Philadelphia was in that year the second shipbuilding state in the Union, ranking next to Massachusetts, which built in 1810, 23,410 ships. However, their value was not as great as those built in Philadelphia, it being only $656,095.[53]

In 1600, when Philadelphia had 3,000 inhabitants, there were 3 master carpenters and 4 master coopers and ropemakers there; in 1717 there were 27 shipwrights and 11 sailmakers and ropemakers—when the city's population was about 8,000; and an examination of the Philadelphia City Directory for 1800 shows that there were then six ship builders—Stephen Beasley, Joshua Humphreys, William and Thomas Penrose, and Isaac White; twelve boat builders; thirty-three

[53] A statement of the arts and manufactures of the United States of America for the year 1810 digested and prepared by Tench Coxe, Esq., in Philadelphia 1814.

ship wrights; twenty-three ship carpenters; seventeen (17) ship chandlers; twenty (20) riggers, and forty-three (43) sail makers, to say nothing of two ship carvers, two ship painters, and two caulkers.

In 1805 the number of ship builders had risen to eight, and in 1810 to eleven; in the latter year, when Philadelphia had 91,874 people, William Brown, John Delavean, four different Eyres, Joseph Grice, Joshua Humphreys, and his son, Samuel, Charles Penrose, and Benjamin Phillips were engaged in this occupation. An examination of the other trades connected with shipbuilding shows, however, a distinct falling off in 1810, as compared with 1805. The ship wrights declined from 93 in the former year to 54 in the latter; the ship joiners from 29 to 13; the sail makers from 43 to 24; the riggers from 30 to 7; the mast makers, from 15 to 5; the caulkers from 15 to 2; the ship carpenters from 9 to 4; and the block makers from 10 to 2. According to the Philadelphia City Directories for 1800, 1805, and 1810, the number of all heads of families engaged in ship building and industries directly connected therewith or dependent thereon was 220 in 1800, 309 in 1805, and 132 in 1810. While it is almost impossible to arrive from the existing figures at anything even faintly resembling an accurate proportion of the inhabitants of Philadelphia men engaged in ship building, it does not seem unlikely that about 10 per cent. were so occupied.[54] In 1800 Philadelphia was the largest city in the United States, as well as the capital; it had 69,403 inhabitants, as against New York's 60,489. Tench Coxe had written in 1794 that "much more of our naval military stores, cordage, twine, nails and spikes, sail cloth, plumber's work, rosin, spirits of turpentine, linseed oil, paints, brass and copper work, and other less important articles expended in building and arming ships are the produce and manufacture of the country, than was the case in 1771," [55] and it seems from the writer's investigation that such articles used in ship building in Philadelphia were even more supplied by that City, or from the United States as a whole, in 1810 than in 1794.

[54] I am greatly indebted to Miss Beatrice d'Este Penrose for culling the above information from the various Philadelphia City Directories. Her zeal, ability and industry in historical research have been of great service to me.

[55] Coxe, *op. cit.*, p. 219.

The following though written by citizens of another ship building and seafaring state is so illustrative of conditions effecting United States shipping in general in 1812 that it fittingly summarizes that situation.

. . . "*But the poor unfortunate merchant, and the once generous brave and happy, but now unfortunate ill-fated mariner, seem doomed to destruction.* Their government does not protect them abroad. If a vessel is visited by the English, for this the French confiscate her. If she is not visited by the English, she is either considered in enemy interest, or an enemy ship under American colours, and for this she is confiscated. If she is so fortunate as to run the gauntlet and escape them all, and returns home, she is then seized, bonded or condemned under some of our own laws, made further to protect the commerce of the United States, and to compel foreign nations to respect our rights. And now after having by our own restrictions almost destroyed the commerce of the United States, exhausted the treasury in persecuting and perplexing our own citizens, by which means many have been ruined, and the spirit of the nation broken down, we are about to declare war against Great Britain (if we give credit to either the professions, or conduct of the administration), and attack her possessions in this country, to protect our commerce to France; when our trade with Great Britain, is of much more importance to us, than all the rest of the world. But in addition to the loss of our exports, and imports in such a war, and the destruction of our shipping, which now amounts to about fifteen hundred thousand tons, which at forty dollars per ton, is sixty millions of dollars, we are to change the present moral and industrious habits of our citizens, for those of idleness and dissipation. Those comforts derived from the importation of foreign necessaries, that we now enjoy at moderate prices, and pay for in our own products, we are to be deprived of, unless at enormous prices, beyond our ability to pay. Our sea ports may be battered down or burnt; our militia, instead of defending their families and friends, are to be taken to Quebec and Halifax, while their own country may be overrun and plundered; and all because Great Britain obstructs our trade with a nation, whose object it is to destroy the commerce of the world; whose commerce to us, under their

present municipal regulations, is not worth having, and a nation from whom we have nothing to fear, but from their pretended friendship." (Address from the Hon. Richard Jackson, Jun and Elisha Potter, Providence, R. I., 1812.)

I am indebted to the George F. Baker Library of the Harvard School of Business Administration, for the above valuable quotation from an extremely rare pamphlet in its possession.

I have endeavored to give you a very brief s[illegible]mary of the first 230 years of the development of shipbuildin[illegible] the River Delaware. It is an inspiring record of what ou[illegible]retathers were able to accomplish under great difficulties [illegible]ats decid[illegible] some of them have returned on December 5, 1931 [illegible]hip [illegible]iners the Delaware at Camden and have seen the l[illegible]ng of the 32,000 ton S. S. Manhattan, the largest mer[illegible] vessel ever built anywhere in America, they would realiz[illegible] that the spirit of Bartholomew Penrose and William West [illegible]d not passed from the activities of that historic river.

Definition of a Snow, page 63:

"A vessel similar in construction to a brig, but the largest of vessels fitted with two masts. It has a square foresail and mainsail, with a trysail abaft, resembling a mizen of a ship, and hoisted by a gaff upon a small mast, c[illegible]se abaft the main mast, which is called the trysail mast."

Brig, page 12:

"A merchant vessel having two ma[illegible]ts, with the wainsail fore and aft, and not athwart ships as in ships."

(Above from "The Elements and Practice of Naval Architecture," London. Printed by C. Whittin[illegible]gham for P. Steel at the Navigation Warehouse, Little Tow[illegible] Hill, 1805.)

The early shipbuilders and shippi[illegible]g merchants in the pre-Revolutionary days in Pennsylvar[illegible] were beset by many hazards not only of the deep but [illegible] pirates, privateers and enemy vessels. It required no sr[illegible]! c[illegible]urage to ship from Philadelphia, down the Delaware [illegible] the broad Atlantic and then to the West Indies or to the [illegible]tish Channel or into the Mediterranean or around the Horn into the Southern Pacific and then to far away China and [illegible]lia!

A letter [56] dated at London in 1757, written in that beauty of almost copper-plate longhand by Robert Plumsted whose descendants later were to make a name for themselves in Pennsylvania, has been preserved and furnishes most interesting insight into the commercial correspondence of the day, as well as into the hazards that confronted the colonial mariner. The letter is addressed to Thomas Penrose (1709–1757), at Philadelphia and was sent "In care of Capt. Bolitho." It is reproduced in full in the following:

THOMAS [illegible]OSE London 9/Mo: 9th. 1757
[illegible]aced.
escape them *friend*

I am [illegible] to acknowledge the receit of thine of 27th 6/th Mo: via Du[illegible]—and observe the Contents.—Capt. Faulkner's Bills upon me, for thy Account shall be duely honourd when they appear. Capt. Lyon was taken by the French in his passage home, and soon after retaken by one of our Privateers, who order'd her into port, but as we have not yet heard of her geting In—fear he is fallen a second time into their hands—thou does not order me to send the Magazines—With Great Regard I am,

Thy Assured Friend
ROBT. PLUMSTED

We can agree that Captain Lyon, in a single return voyage from Philadelphia to London, met with somewhat romantic experiences, in the Year of Grace, 1757. Mention has already been made of the use of oak in building Philadelphia ships. The following may be of interest as showing how oak trees were taken from Philadelphia to Russia in 1830 in order to improve the Russian Navy.

[56] The original of this lett[illegible] is in the possession of Charles Penrose, Esq. (*Princeton 1907*), of Uwchlan [illegible]wnship, Chester County, Pennsylvania. The Captain Lyon mentioned is Ca[illegible]in Charles Lyon of Philadelphia, the author's great-great-grandfather. [illegible]e [illegible]mmanded and partly owned the brigantine Polly of 20 tons, which was at [illegible]adelphia on Sept. 17, 1760.

ONE HUNDRED YEARS AGO.

(From the *Philadelphia Evening Bulletin* of September 24, 1831.)

We had the satisfaction of visiting Mr. Carr's (late Bartram's) Garden at Gray's Ferry in the early part of the week and seldom have we spent a day more agreeably. In this area of about 30 acres it is believed that every tree belonging to North America is to be found. Florida and the luxurient latitudes of the Gulf have many representatives in this great congregation of the trees of North America. Among the Southern plants is a cypress from Florida planted by Mr. Bartram, the founder of the garden; it is now 93 years old and presents the greatest mass of timber we ever beheld in a single tree, besides standing up a living pillar of unrivalled beauty. The collection of exotic plants is very extensive—all quarters of the world have rendered tribute to Mr. Carr's industry. His collection of grapes includes nearly 200 varieties. He has just commenced a vineyard of three acres in which no less than 112 different kinds have been planted. Cuttings from all these can be procured at a moderate price, and in any quantity that may be required. The garden also contains miniature forests or nurseries of oaks of various kinds. The demand for these from Europe is very great. The Kensington took out nearly a thousand dollars' worth for the Russian Government to be planted in the Royal grounds as nurseries of the Navy, and to extend the culture of American oak throughout Russia. To the charms of this fascinating spot were added the polite attentions of the proprietor and his son to whose obliging kindness we feel indebted for more than half the pleasure of our visit.

The following references from the New York Commercial Advertiser for 1801 would appear to indicate that Philadelphia-built vessels were on sale not merely at their home port but also at that of her rival. We read in an advertisement in the issue of that paper for March 29, 1801 of the brig *Amiable Matilda* which John Townsend offered for sale, that she was built in Philadelphia of live oak and cedar, of 231 tons burthen, and had been coppered in London about fifteen months before. This Philadelphia-built vessel "is considered one of the best vessels belonging to the Port of New York."

She had apparently returned shortly before from a journey to some West Indian port, since in the same advertisement John Townsend offers "592 boxes of white sugar and 219 boxes of brown sugar" which were being unloaded from her. In the issues of January 14 and 16, 1801, of the same newspaper "The well known ship *Citizen*, C. Blakeman, master, built in Philadelphia of live oak and cedar" was advertised for sale. She had been "newly coppered in Liverpool" and had just brought a cargo of coal from Liverpool to New York City!

In the issue of the "Colombian Centinel" of Boston, Massachusetts, for March 25, 1801, there is an advertisement to the effect that T. K. Jones will auction, on Friday, March 27, 1801:

"The brig Nymph, 187 tons burthen, built at Philadelphia, of live oak and cedar is a strong and very burthensome vessel, sails fast and has elegant accommodations. The sale will be on board at Hancock's Wharf. Conditions liberal and will be made known at the sale."

It may, therefore, be inferred that Philadelphia-built vessels were a factor in "interstate commerce" at the close of John Adams' Presidency and the beginning of Jefferson's.

In the issue of the "Colombian Centinel" of Boston for April 4, 1801, in the course of a violent attack on the Jefferson Administration for reducing the United States Navy, the disasters that will ensue from this measure in the United States as a whole are enumerated and discussed and the statement is further made:

"and what consolation must it (this naval reduction) afford to the farmer who furnishes ship timber, the ship carpenter, blacksmith, ship joiner, painter, rigger, boat builder, mast maker, block maker, sail maker, rope maker, caulker, carver."

The Prized Pearls of Industry.—(The *Du Pont Magazine*, Feb. 1932.) Most of us are familiar with the beautifully iridescent finishes exhibited by many pyroxylin plastic materials. Some believe these are prepared by adding fish scales to the material when it is in a fluid workable condition. That is not exactly so. This shiny lustrous substance consists of "guanin crystals" and although not the same as fish scales, at least they are found closely associated with them. These crystals are actually deposited in the epidermis or outer skin of the fish and when the scales are removed a portion of these crystals remain adhering to them. While still fresh these scales are washed with soap and water. Next, the pearly crystals are scrubbed off the scales in a large agitator. The crystals being lighter than water come to the top while the scales and any dirt sink to the bottom. After the crystals have been freed from water by centrifuging they are placed in an organic solvent which removes the grease and oils. After standing twenty-four hours they are once more centrifuged. The crystals are now in the form of a watery paste. To this is added ordinary clear lacquer. The guanin crystals are preferentially wetted by this lacquer and go over to it leaving the water and other foreign particles behind. The "pearl" essence thus obtained is now ready for mixing with plastics and other ingredients to give objects having attractive and unique appearances.

T. K. C.

Blasting Poles into (not out of) the Ground.—K. H. WILLIAMS in the *Du Pont Magazine* for Feb. 1932 describes a paradox in explosions. A South American power company were unable to pull a large pole from the ground even after exerting a pulling force equal to sixty-five tons. In an attempt to loosen the pole a charge of dynamite was placed under it and fired. Result: The pole dropped five or six feet further into the ground. This peculiar property of an explosive is now being used as an aid to placing poles in soft, marshy and boggy ground. A narrow hole is sunk to the desired depth by means of a bar or auger operated inside a pipe of slightly larger diameter. The charge is placed at the bottom of the hole and the pole placed in an upright position, its bottom resting upon the mouth of the opening. The charge is fired and the pole immediately sinks to the bottom of the hole. With a little practice they can be set to within half an inch.

T. K. C.

THE EFFECT OF CERTAIN MONOCHROMATIC ULTRAVIOLET RADIATION ON EUGLENA CELLS.[1]

BY

W. F. G. SWANN,

Director of the Bartol Research Foundation of The Franklin Institute

AND

C. del ROSARIO,

Fellow.

BARTOL RESEARCH FOUNDATION

Communication No. 65.

Introduction.—The killing of unicellular organisms by radiation has been studied by several investigators. Some of the most recent work has been done by F. L. Gates, R. W. G. Wyckoff, and by the present authors.[2] In their former papers,[2] the writers have described experiments on the killing of euglena cells by means of alpha particles. It was found that the rate of death of the cells was proportional to the number present and to the intensity of the alpha-particle radiation, a result which enabled us to conclude that death was caused by a

[1] The investigation was carried out, through the aid of a grant, under the auspices of the Cancer Research Fund, Graduate School of Medicine, University of Pennsylvania. The experiments were conducted by the junior author under the direction of the senior author, who is also responsible for the theoretical treatment.

[2] F. L. Gates: "Bactericidal Action of Monochromatic Ultraviolet Light," *Jour. Gen. Physiol.*, **13**, 231–248, 249–260, 1929.

F. L. Gates: "Absorption of Ultraviolet Light by Bacteria," *Ibid.*, **14**, 31–32, 1930.

R. W. G. Wyckoff *et al.*: "Killing of Colon Bacilli by Cathode Rays," *Jour. Exp. Med.*, **51**, 921, 1930.

R. W. G. Wyckoff *et al.*: "Killing of Colon Bacilli by X-rays," *Ibid.*, **52**, 435, 769, 1930.

"The Mechanism of the Process of Cell Destruction under Bombardment by Alpha Particle Radiation" (W. F. G. Swann and C. del Rosario). Report on the Work of the Bartol Research Foundation for 1929–1930, presented before the April Meeting of The Franklin Institute, 1930, and published in the *Jour. Franklin Inst.*, **210**, 778–784, 1930.

W. F. G. Swann and C. del Rosario: "The Effect of Radioactive Radiations Upon Euglena," *Ibid.*, **211**, 303, 1931.

single impact with some sensitive entity in the cell itself, rather than by a process in which two or more impacts were necessary, with possibilities of recovery between them. It was possible to go further; and, by knowledge of the intensity of the radiation, to deduce the actual size of the sensitive entity which, when struck by the alpha particles, caused death. It was very interesting to find that the size of the entity was about equal to that of the nucleus of the cell. The authors have now extended this work to the killing effect caused by certain monochromatic radiations in the ultraviolet region. The present paper is an elaboration of the results already published by the authors upon this subject.[3] No particular claim is made as to originality of procedure in the matter of the questions investigated, and the processes adopted are such as would be natural to any experienced worker in the field. The points of view elaborated have doubtless occurred to many who have thought about the question, or have investigated it. Since the publication of the foregoing work, a paper has appeared by R. W. G. Wyckoff,[4] covering very much the same field, and with very similar conclusions. An interesting communication on the lethal effect of ultraviolet radiation upon euglena cells has also been presented by Ellice McDonald and A. J. Allen.[5] This paper deals with the microscopic examination of the lethal effect of ultraviolet radiation, and is very interesting as indicating the qualitative features which accompany the death of the organisms.

On extending the work from alpha-particle radiation to ultraviolet radiation, certain very characteristic differences immediately made themselves evident. In the first place, it was noted that the rate of dying of the cells was not related in any obviously simple manner to the intensity of the light

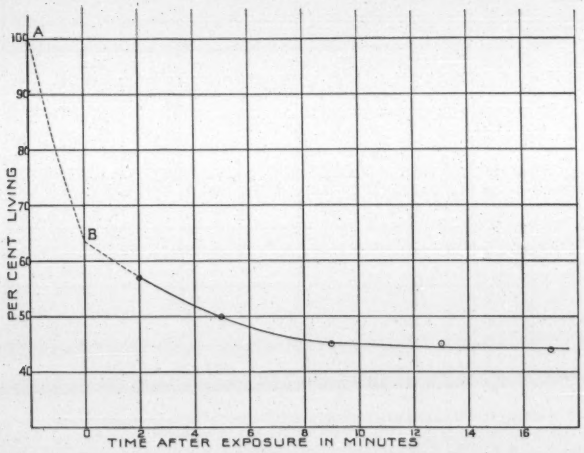
[3] "Experiments on the Effect of Radiations in Causing Death in Living Cells" (W. F. G. Swann and C. del Rosario). Report on the Work of the Bartol Research Foundation for 1930–1931, presented before the April Meeting of the Institute, 1931, and published in the *Jour. Franklin Inst.*, **212**, 756–762, 1931.

[4] R. W. G. Wyckoff: "The Killing of the Colon Bacilli by Ultraviolet Light," *Jour. Gen. Physiol.*, **15**, 351, 1932.

[5] "Monochromatic Ultraviolet Radiation Effects upon Single-Celled Organisms, with a Quartz Microscope" (A. J. Allen and Ellice McDonald). Presented before the 82nd Meeting of the American Chemical Society, November 2, 1931.

and to the number present, but it was affected by the time that the light had been in operation; cells did not cease to die immediately the light was shut off. It was as though the light made them sick, but the death followed sometime later. On the other hand, it appeared that if the light were supplied for a certain time and the total quantity of light which had fallen upon the cells during this time was estimated, then the total number of euglena cells which died subsequently as the result of this exposure was proportional to the total quantity of light in question, within the limits of intensity and concentration investigated. The results in this connection are well illustrated in Figs. 1 and 2. In Fig. 1, the

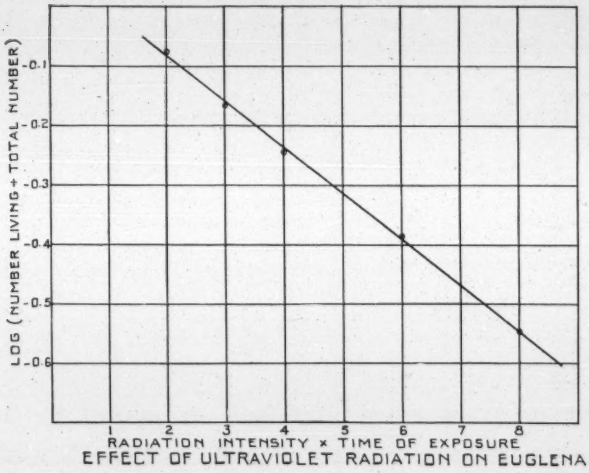
FIG. 1.



horizontal axis represents the time, and the vertical axis the percentages of the original number of euglena cells still living. We start before the application of the light, and, of course, the percentage living is 100. Then, at the point A, for a period of two minutes, during which no observations were taken, light was applied. The light ceased to be applied at $t = 0$. Then, as will be seen, the death of the cells continued

quite actively for a period of the order of ten minutes or more. Figure 2 shows the logarithms of the number of cells living divided by the total number, plotted against the amount of light to which the cells had been exposed, as represented by the product of the radiation intensity and the time of exposure. Incidentally, it was found that the number which ultimately died depended uniquely upon the product of intensity and time of exposure and not upon the way in which that product was made up. In other words, the same killing is obtained

FIG. 2.



EFFECT OF ULTRAVIOLET RADIATION ON EUGLENA

with an intensity I applied for an exposure time t, as is obtained by an intensity 10 I applied for a time one-tenth t. The linearity of the graph in Fig. 2 shows that the percentage of the cells killed by the radiation is proportional to the total amount of radiation estimated in the sense above implied.

In work of this kind, it is of importance to know the degree of consistency and reliability of the results. For this reason, the following table is given, illustrating the extent of such consistency in the different experiments. The final

results, recorded in Table II, represent the averages of many experiments for each wave-length, but it will suffice to record in Table I five representative sets of data for two different wave-lengths, the variations in these data being representative of the general variations from experiment to experiment. In Table I ΔN represents the number of deaths in the time t after algebraical addition of the quantity δN, representative of the decrease or increase of the number of living cells as obtained from the control in the absence of ultraviolet light. Increases, of course, occurred as the result of cell multiplication, and as to whether increase or decrease prevailed was probably determined by the nature of the cells and the general conditions prevailing. N_0 represents the original number of cells present. I is the intensity of the light, and the consistency of the numbers in the last columns for each wave-length is indicative of the general consistency of the observations.

TABLE I.

Wave-Length.	ΔN.	δN.	N_0.	I Arbitrary Units.	t Seconds.	$\frac{\Delta N}{N_0 I t}$.
2536 Å	72	0	101	4	200	8.9×10^{-4}
2536 Å	55	1	83	4	200	8.3×10^{-4}
2536 Å	68	3	85	4	200	9.3×10^{-4}
2536 Å	62	1	90	4	200	8.6×10^{-4}
2536 Å	50	3	69	4	200	9.1×10^{-4}
2894 Å	10	3	106	1.7	600	9.5×10^{-5}
2894 Å	8	0	110	1.7	600	7.3×10^{-5}
2894 Å	10	1	92	1.7	600	10.9×10^{-5}
2894 Å	6	3	61	1.7	600	9.8×10^{-5}
2894 Å	6	2	86	1.7	600	7.0×10^{-5}

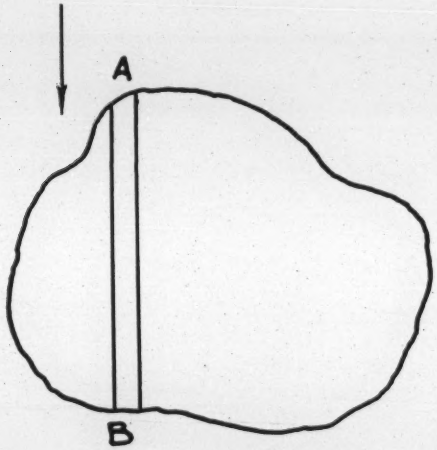
Theoretical Considerations.—The theoretical elements which enter in the case of ultraviolet light are somewhat different from those entering in the case of alpha particles, in view of the fact that the light in passing through the liquid is absorbed exponentially, whereas the alpha particle has a definite range. We shall trace the consequences of assuming that there is, in the cell, a sensitive entity of volume v, such that in a fraction p of the cases where a quantum of light is absorbed within that volume, death follows.

If light of intensity I passes through the sensitive entity in the direction indicated by the arrow, Fig. 3, the amount of light absorbed per sec. in the column AB of cross section da and length l is

$$\Delta I = I(i - e^{-\mu l})da, \tag{1}$$

where μ is the coefficient of absorption of the light.

FIG. 3.



If the percentage absorption in the column is small,

$$\Delta I = I\mu l da, \tag{2}$$

and the absorption for the whole sensitive entity is

$$\delta I = I\mu \Sigma l da = I\mu v. \tag{3}$$

The number of quanta absorbed per second is δn where

$$h\nu \delta n = \delta I, \tag{4}$$

ν being the frequency of the light and h Planck's constant.

Thus,

$$\delta n = \frac{I\mu v}{h\nu}. \tag{5}$$

If N is the number of euglena cells exposed to the light; and, if in accordance with the foregoing assumption, a fraction p of those absorbing a quantum die, we have for δN, the number dying as a result of exposure for a time δt

$$\delta N = \frac{pNI\mu v}{h\nu}\,\delta t \tag{6}$$

and

$$\log \frac{N}{N_0} = \frac{p\mu v}{h\nu}\,It, \tag{7}$$

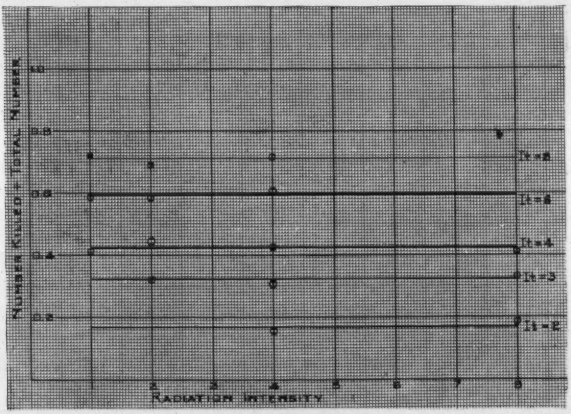
showing that $\log \frac{N}{N_0}$ is proportional to It as the experiment shows to be the case, and providing a means of evaluating pv if I, μ and ν are known. The foregoing calculation is valid if there are several sensitive entities of the same kind in each cell, so long as v refers to the sum of the volumes of the entities for the whole cell.

Experimental Method.—The water containing the euglena was placed in a vessel with a shallow, circular cavity similar to that used in the previous work but the upper glass plate was replaced by one of quartz so that the ultraviolet radiation could reach the cells beneath. Before exposure to the radiation, the euglena in this container, and those in a similar one used as a "control," were counted to make sure that conditions were right for the healthy existence of the cells. It was first desired to test the relationship between the number of deaths and the product of light intensity multiplied by time of exposure, in order to see whether the number of deaths depended upon this factor but was otherwise independent of the components of which the factor was made up. For this purpose, monochromatic light was not necessary, and the procedure was to expose the euglena to the radiation from a quartz mercury arc at a given distance away, for a given duration, and then repeat the experiment with other distances and correspondingly different durations of exposure. Figure 4 summarizes the evidence in this connection. The ordinates represent the number of euglena killed, expressed as a fraction of the total number. Each of the horizontal straight lines corresponds to a definite value of It as recorded at the end of those lines, and the abscissæ indicate the value of I corre-

sponding to the fixed value of It. The fact that the lines are horizontal lines parallel to the horizontal axis shows that the number of euglena cells killed depends only upon the factor It and is otherwise independent of each of the components.

The main observations were made with monochromatic light obtained from a Kipp and Zonen quartz monochromatic illuminator. The exposures were made by placing the small rectangular container for the euglena specimens at a fixed distance from the emergence slit of the illuminator for a measured time. Subsequently it became necessary to know

FIG. 4.



the amount of radiant energy of the corresponding wavelength falling upon the specimen in the position which it occupied. For this purpose, a sensitive thermopile was used in conjunction with a galvanometer, and it was subsequently standardized in absolute units by exposing it to the radiation from a theoretical black body. The black body was made by winding upon a porcelain cylinder 2 cm. in diameter a coil of nichrome wire which could be heated by an electric current. The cylinder was then covered with a thick layer of asbestos. The opening to this black body was closed by a hole 1 cm. in

diameter, and the radiation intensity R at a distance r from this hole was calculated from the relation,

$$R = \frac{\sigma}{\pi}(T_1^4 - T_0^4)\frac{S_1 \cdot S_2}{r^2},$$

where

σ = 5.7×10^{-5} ergs cm.$^{-2}$ sec.$^{-1}$ deg.$^{-4}$;
T_1 = Temperature of the black body;
T_0 = Room temperature;
S_1 = Area of the opening of the black body;
S_2 = Area of the opening of the thermopile.

It was necessary also to measure the absorption coefficient of the cell. This represents the most uncertain part of the experiment; for, what is really desired is the absorption coefficient corresponding to the sensitive entity. While the cells seemed fairly uniform in their structure when viewed by ordinary light, very marked differences of absorption showed themselves when ultraviolet light was used. It is possible to obtain the absorption coefficient, or rather the average absorption coefficient for any point of the visible area of the cell, the average being an average for the whole thickness of the cell measured parallel to the direction of the light at the point considered. It is also possible, by a microscopic estimation of the size of the various parts of the cell which show different absorptions, to calculate for those parts the absorption coefficients. The measurement of the absorption involves obtaining a photographic densitometer record of the light transmitted through various portions of the cell. For this purpose, a Kruss automatic recording densitometer was used. For the purpose of obtaining the average coefficient of absorption through the depth of the cell at any point of vision, the procedure was to compare the densitometer record for that point with the record obtained with the cell absent but with the light passing through the quartz coverslip, etc. It is possible to divide the cell into two main regions as regards the absorption of its material. The absorption coefficient for the regions of minimum absorption was obtained in the manner above indicated. For the regions of maximum absorption, the procedure was to obtain, from the densitometer

record, the light absorbed in passing through the cell so as to include one of these regions. Then, from a knowledge of the dimensions of the region, compared with the dimensions of the cell itself, it was possible to subtract the absorption of the less absorbing parts through which the light had passed, on the basis of the measurements of the minimum absorption coefficient.

It was found that the lethal effect of the ultraviolet radiation was strongly characteristic of the wave-length. Radiation of wave-lengths 3654 Å, 3132 Å, 2894 Å, and 2536 Å were tried. The wave-length 2536 Å showed a considerable lethal effect; the 2894-Å line had a much smaller effect, while the other two had no measurable effect.

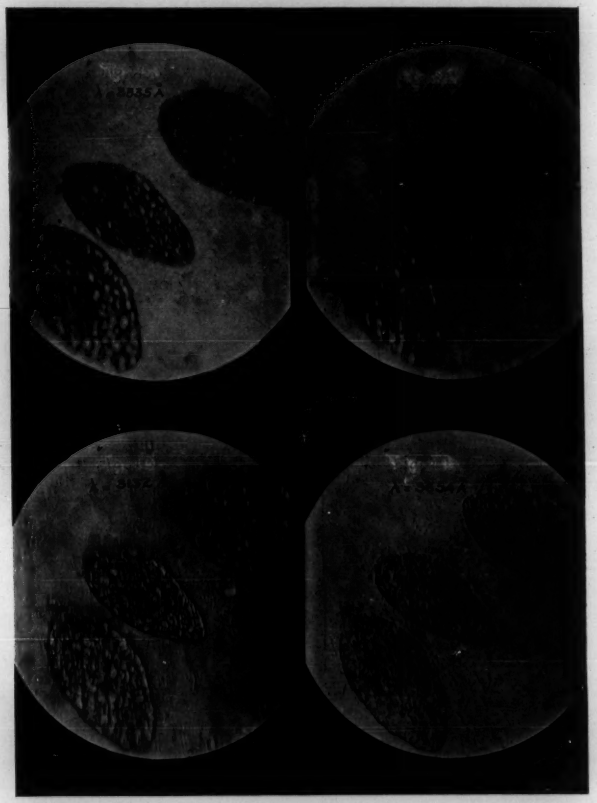
The data as regards the killing for the lethal wave-lengths is summarized in Table II, where the fifth column gives the volume of the sensitive entity on the assumption that p is equal to unity, and the sixth column gives the value of p on the assumption that the size of the sensitive entity is equal to that of the nucleus. The second column represents the fraction of the cells present which are affected per second in such a way as ultimately to result in death. The third column, represented by n, gives the number of quanta per square centimeter per second falling upon the cells at the point of observation. It is equal to $I/h\nu$, where I is the intensity of the radiation obtainable from the thermocouple measurements.

TABLE II.

Wave-Length in cm.	$\frac{1}{N}\frac{dN}{dt}$	n.	μ.	Vol. of Sensitive Entity.	p.
2536×10^{-8}	3.7×10^{-2}	7.5×10^{13}	3×10^{-1} 9×10^{2} (nuc.)	5.5×10^{-20} cc.	9×10^{-10}
2894×10^{-8}	1.5×10^{-4}	3.3×10^{13}	2×10^{-1} 2×10^{2} (nuc.)	2.3×10^{-20}	4×10^{-10}

It is of interest to inquire whether the difference in lethal effects of the different wave-lengths is simply a result of difference of absorption of light or whether it is intrinsically a characteristic of the wave-lengths apart from such differences in absorption. Figure 5, which was kindly supplied by Dr. A. Allen, of the Cancer Research Laboratories, shows photo-

FIG. 5.



graphs of the euglena cells taken with the wave-lengths indicated in the Figure, which wave-lengths were those used in the main experiments. It will be seen that the nucleus absorbed markedly radiations of wave-lengths 2536 Å and 2894 Å, which were lethal for the cells, while the wave-lengths

3132 Å and 3654 Å, which were non-lethal, were transmitted without any more absorption than that which characterized the remainder of the cells.

The value of μ for the 3132-Å line was 0.2, and, in a certain experiment n was 9.5×10^{13}. Under these conditions, the number of quanta absorbed per second by the whole cell was, say, α where

$$\alpha = 9.5 \times 10^{13} \times 0.2v_0,$$

v_0 being the volume of the cell. On the other hand, we see, from the data given in Table II, that the number of quanta of the 2536-Å line absorbed per second by the cell was, say, β where

$$\beta = 7.5 \times 10^{13}\{0.3(v_0 - v) + 900v\},$$

where v is the volume of the nucleus. Since $v/v_0 = 1/150$, this gives $\alpha/\beta = 0.04$.

Now, it is certain that the rate of killing of the cells by the 3132-Å line was less than 4 per cent. of that for the wave-length 2536 Å. In fact, the consistency of the observations was such as to enable one to say that it was certainly less than 1 per cent. Hence, the predominance of the lethal effect of the 2536-Å line over that for the 3132-Å line is not explicable entirely as a matter of absorption but involves, in addition, other characteristics of the wave-lengths concerned. Similar conclusions may be drawn from the experiments on the 3654-Å line, for which $\mu = 0.1$. Here, with $n = 12 \times 10^{13}$, there was certainly less than 1 per cent. of the killing caused by the 2536-Å line.

In conclusion, it must be remarked that the description of the phenomena in terms of a sensitive entity is only intended as a rough guide in the formulation of a picture of the process, particularly in view of the small value of p. The inclusion of the factor p in the calculation, moreover, widens the significance of the sensitive entity to include as a possibility the whole cell as representative of the entity; and, even then, p may vary from point to point in the cell.

BARTOL RESEARCH FOUNDATION OF
THE FRANKLIN INSTITUTE,
January 28, 1932

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE COLOR RANGE OF COMMON BRICK.

As part of a survey of the properties of common brick produced in the United States a record was made of the colors of 3900 bricks collected from over 200 manufacturers representing all parts of the country. There is here given a rather generalized description of the color of bricks by district. The following abbreviations are used for the several methods of forming: S. M. (soft mud); D. P. (dry press); S. C. (side cut); and E. C. (end cut).

Name of District.	Number of Plants.	Methods of Forming.	General Color Range.
Maine, New Hampshire, Vermont.	9	S. M.	Deep reds and browns with some fawn color and drab.
Massachusetts.	15	S. M. (one S. C.)	As above. Also medium reds and orange reds.
Connecticut.	12	S. M.	Deep red and deep orange reds to medium reds and orange reds with some browns, fawns and drabs.
Hudson Valley.	18	S. M.	Smoked medium reds and medium orange reds. Blotching of dull greens and pinks.
New Jersey.	10	S. M., E. C., S. C.	In part like Hudson Valley and medium red and orange red on light brown.
Eastern Pennsylvania and Delaware.	20	S. M., S. C.	Dark and medium red and purplish red.
Western Pennsylvania and West Virginia.	10	S. C.	Dark reds, usually dulled with gray. Some dark flashing.
Northern Ohio.	11	S. M., S. C.	Highly variable.
Detroit.	6	S. M.	In part resembles Connecticut, otherwise medium and light red orange.
Chicago.	9	E. C.	Light buff and cream with irregular pinkish markings.
Wisconsin.	6	S. M., S. C.	Pale buff to light cream. Some grades resemble Hudson Valley production.
Kentucky.	6	D. P., S. M., S. C.	Dark reds and purplish reds.

Table continued on next page.

* Communicated by the Director.

Name of District.	Number of Plants.	Methods of Forming.	General Color Range.
Illinois and Missouri.	12	D. P. and S. C.	Medium and dark red and medium red orange. Some dark purplish red.
Nebraska.	5	S. M. and S. C.	Medium and light red and red orange with some blue black slag.
Colorado.	8	D. P. and S. C.	Medium and light red and orange red. Some cream and brown.
California.	4	S. M. and S. C.	Medium red and medium red orange.
Texas.	15	D. P., S. C., and E. C.	Light red and light red orange.
Louisiana and Mississippi.	7	E. P., S. M., S. C., E. C.	Spotting and speckling of black and brown common. Fawns, drabs, browns, medium and dark reds, medium red orange and medium purplish red.
Alabama.	4	D. P. and S. C.	Dark, medium and light red with some medium red orange. Flashes of dark gray and purple gray.
North Carolina.	4	S. C. and E. C.	Dark and medium red and red orange with overlay of brown and flashes of drab.
Virginia.	8	S. C.	Dark to light red and red orange.
Maryland and District of Columbia.	7	D. P., S. M., S. C., and E. C.	Dark and medium red.

The complete report of this survey will be found in the April issue of the *Journal of the Clay Products Institute* (c/o Mr. J. A. Pugh, Evans Building, Washington, D. C.).

CURING CEMENT UNDER HIGH TEMPERATURES.

The steam curing of Portland cement products has been of interest ever since the original experiments several decades ago demonstrated the high early strength that could be obtained. The recent discovery that steam curing was in general satisfactory and was the only method of making the products resistant to disintegration by the alkali waters prevalent in the Western States, made the process of still more interest.

There is the unsettled question as to whether all Portland cements will react favorably to the steam curing. Recent experiments by Woodworth (*Proceedings of the American Concrete Institute*, Vol. I, p. 504) included tests in which the steam curing was begun within half an hour after molding

instead of after the usual wait of from 18 to 24 hours that permitted the cement to attain an initial strength. The behavior of Portland cements of different characteristics to this type of curing should be of general interest, particularly to the manufacturers, and a short series of tests was undertaken by the bureau.

Four cements were used; a high early strength Portland, one made from Lehigh Valley Cement rock, one from marl and clay, and one made from limestone and clay. The tricalcium silicate ranged from 53.5 to 68 per cent., not a wide range, but the minor constituents varied considerably. Mortar specimens, made up with run of mine Ottawa silica sand were prepared, half the specimens being stored in steam, the other half in boiling water. The steam or water curing was continued for 16 hours, the specimens being placed in the steam or water 1/2 hour after mixing. Comparative specimens were cured in the standard damp closet for 24 hours, then stored in water until tested.

The steam or boiling water curing gave material strength increases at 24 hours, but at 7 and 28 days very little difference in strength was noticeable. It is to be noted that the increase in strength at 24 hours was not similar for all cements.

The detailed description of the tests and the test results will appear in the April, 1932 issue of the *Journal of the American Concrete Institute.*

BASE EXCHANGE CAPACITY OF CLAYS.

In connection with the investigation of the properties of several groups of clays the base exchange capacities were worked out.

The total base exchange capacity was determined by electrodialyzing samples in two compartment cells constructed for this type of work, and finding the milliequivalents of hydrogen ions held by the clays in the adsorbed condition, by electrometric titration using $Ba(OH)_2$ as the neutralizing base.

In correlating the results with physical properties the most interesting relation developed in connection with the dry transverse strength. If the modulus of rupture, in lbs. in.^{2}, is plotted against the milliequivalents of electrodialysable

bases per 100 grams of the dry clay, it will be found that the tendency of the plotted points is to form a straight line starting near the origin and having a slope of about 200 pounds p 10 milliequivalents. The china clays form a group near t lower portion of the line, and most of the ball clays at higher end. The so-called "heavy clays," or those in comm use for the manufacture of heavy clay products such as face brick, group in between the china clays and the balls, tending in general to lie fairly high on the line among the ball clays. These latter clays tend to show the poorest correlation due to the large amounts of impurities they carry, or perhaps to the wider variation in size of constituent particles. The glacial type clays in particular show higher transverse strength than one would expect from their base exchange capacities.

PERMANENT PHOTOSTAT PAPER.

The bureau has coöperated with the Library of Congress and other public libraries in choice of photostat papers for reproducing records in permanent form. Photostat prints are considered to be as permanent as the paper bearing them, provided the sensitizing and printing are done by the best procedure. A large number of foreign and domestic photostat papers have been tested, mainly for the Library of Congress, to determine their suitability for reproducing records of early American history stored in libraries abroad.

This class of paper has been found to compare very favorably with other permanent types, if care has been taken to introduce no excessive amounts of deteriorative chemicals, particularly acid, in the sensitizing treatment. Papers from different sources have shown the following excellent characteristics for permanent records: Free from unbleached or ground wood fibers; weight: 25 by 40 inches, 500 sheets, 64 pounds; folding endurance: over 2000 double folds in each direction, and retaining over 75 per cent. of the folding endurance when heated 72 hours at 100° C.; copper number less than 1.5; alpha cellulose over 90 per cent., and not decreasing more than 2 per cent. under the heat test mentioned; acidity less than the equivalent of 0.1 per cent. SO_3. Owing to its great folding strength, paper such as this is particularly suitable for

records subjected to much handling. The papers tested showed a wide range of folding endurance, which in one case was as low as 6 double folds. However, as many of these in other respects possessed the same characteristics as listed above, they would no doubt be suitable for records which would be handled but little.

In developing the prints, precautions should be taken to avoid excessively high temperature, impure chemicals, and inadequate washing-out of the developer. The test data given are for papers that had been developed.

PHOTOGRAPHIC DEVELOPERS.

It is well known that the characteristics of photographic emulsions depend to some extent upon the kind of developer and the particular formula by which it is made up. For many years pyrogallol has been much used for sensitometric work. However, for general photography, pyro developers have now been largely replaced by metol-hydroquinone and there is a growing tendency to use the latter in sensitometry as well. The International Congress of Photography is considering recommendations concerning the use of either para-aminophenol or metol-hydroquinone as a standard developer for sensitometric purposes.

A study has been commenced at the Bureau of Standards of the suitability of metol-hydroquinone for this purpose. While not yet completed, some 8 groups comprising 35 formulas have been investigated. The general formula, showing the constituents so far employed and the range of variation of each, is as follows:

Metol	0 to 16	g. per liter.
Hydroquinone	0 to 20	do.
Sodium sulphite	10 to 160	do.
Sodium carbonate	1 to 100	do.
Potassium bromide (only present in the last group)	0 to 2	do.

For each formula, the following characteristics were measured at each of six times of development ranging from 1 to 18 minutes: (1) Contrast, measured by γ (the slope of the straight portion of the characteristic curve); (2) fog density; and (3) sensitivity or speed, measured both by the inertia and by the minimum useful gradient.

In each group, a single ingredient was varied and the changes in the three characteristics were noted.

In the first, the variable was the sulphite content. Increasing the sulphite from 10 to 80 g. per liter, increased the fog density and decreased values of γ. With 160 g., both the and fog density were greatly reduced. Since the ratio on with which the developing solution deteriorates decreases as the sulphite content increases, about 20 g. per liter were found necessary to preserve the solution at least long enough to carry out the development.

In the second group using this quantity of sulphite, the carbonate content was then varied. Increasing the carbonate, increased both γ and fog density for a given time of development (i.e., the development was accelerated). A conveniently rapid developer may be obtained with 5 to 10 g. per liter. With more than about 50 g., the increase in rapidity is very small.

In the third and fourth groups the same variation of the carbonate was repeated, omitting first the metol and then the hydroquinone. The results demonstrated that the action of these two developing agents in combination cannot be predicted from their behavior separately. The hydroquinone developers with less than 50 g. of carbonate per liter were not sufficiently rapid, and in all cases the fog density was excessive with long development times; at the same time the sensitivity of the plate was greatly reduced. Neither metol nor hydroquinone produced as high values of γ separately as in combination. Increasing the carbonate content of this metol developer above a minimum (about 5 g. per liter) did not affect the rapidity of development. For the fifth group the fourth was then repeated using 8 g. (4 times the previous quantity) of developing agent. It was still impossible to attain the maximum value of γ obtained with the metol-hydroquinone combination.

In the sixth and seventh groups, the ratio of metol to hydroquinone was varied. In one, the metol was kept constant while the hydroquinone was varied. Increasing the hydroquinone (above 5 g. per liter) resulted in moderately lower values of fog density at all development times and somewhat higher values of γ at the long times. In the other,

reco[illegible]ydroquinone content was fixed and the metol varied. sho[illegible]sing the metol (about 2 g.), increased the fog density was [illegible]tly but did not increase the maximum value of γ ob- oth[illegible]able.

abo[illegible]n all of these seven groups, the developers were without wo[illegible]assium bromide. The eighth group was concerned with [illegible]e effect of additions of this constituent. As the bromide was increased, values of γ and sensitivity were greatly reduced with short times of development, while with prolonged development both characteristics were considerably increased. The fog density at all times of development varied inversely with the bromide content.

FURTHER STUDIES OF PHOTOGRAPHIC EMULSIONS.

The April number of the *Bureau of Standards Journal of Research* will contain a report on the bureau's investigations of photographic emulsions, following several which have already appeared in the *Journal*.

The report is introduced by discussions of previous experimental and theoretical work on silver and hydrogen ion concentrations in emulsions, and a description of experimental [illegible]hnique. These variables are taken up first according to [illegible]eir effects on after-ripening, and second according to their [illegible]ect effects on sensitivity when changes in after-ripening [illegible] eliminated (in experiments after digestion). The rate of [illegible]ter-ripening increases with increasing silver ion concentration and increasing pH; the corresponding effects on sensitivity are much larger than those produced by the direct effect on environment (after digestion). The combination of silver ion with gelatin reduces the effect of excess silver; illustrations are given for the distribution of excess bromide or silver in the emulsion with changing pH. The desensitizing action of bromide (after digestion) is found to increase with increasing acidity; conversely, the effect of pH is dependent on the silver ion concentration. Spectral sensitivity of the emulsions is found to be independent of hydrogen or silver ion concentrations; these variables must, therefore, influence sensitivity through secondary reactions in latent image formation. Results are discussed in terms of a new concept of the adsorption

of gelatin to silver bromide, based on the "zwitterion" theory of ampholytes.

INFRA-RED SPECTRA AND IDENTIFICATION OF FRAUNHOFER LINES.

The discovery of new infra-red sensitizers by the Eastman Kodak research laboratories makes it possible to record spectra photographically considerably beyond the former limit. In fact, the infra-red range now accessible to photography has been more than doubled. The infra-red spectra of 40 chemical elements have now been explored with these new plates, and in most cases many new lines have been discovered. These new data make it possible to confirm and extend the analyses of spectral structures and thus verify the theory of atomic structure.

Our knowledge of the chemical constitution of the sun is based on the identification of spectral lines characteristic of the chemical elements in the laboratory with the dark (Fraunhofer) lines observed in the solar spectrum. The presence of 57 chemical elements in the sun's atmosphere has thus been established. More than 20,000 dark lines have been charted in the solar spectrum, but less than 12,000 of these have been identified with known spectra. The remainder are mostly faint lines and many of these will be explained when the laboratory data on emission spectra become more complete. For example, practically all of the new infra-red lines observed for iron and silicon in the laboratory have also been found in the sun. The case of silicon is of special interest because it is one of the most abundant elements in the sun but its spectrum is characterized by a relatively small number of lines. The number of silicon arc lines identified with solar lines has now been increased from 27 to 50 and includes the strongest Fraunhofer line heretofore unidentified.

AIRPLANE RECEIVING EQUIPMENT FOR VISUAL RADIO RANGE-BEACONS.

Radio is used in two principal ways as an aid to air navigation. One of these is communication and the other is directional guidance. On the airways of this country, direc-

tional guidance takes the form of radio range-beacon stations which send out direction signals which enable the airplane pilot to navigate the established course along the airway without the use of directional apparatus aboard the airplane.

The bureau, serving as the research division of the Aeronautics Branch of the Department of Commerce, continuously carries on research for the improvement of this and other radio aids to air navigation. The radio range-beacon is now available in two forms, one in which a signal is received aurally by the airplane pilot, and one in which a visual indication on the airplane instrument board tells the pilot whether he is on course or off to the right or the left. The visual indicators and associated equipment have become commercially available. Airplane operators and others have expressed a desire for information on the installation and use of such equipment. To meet this, the bureau has prepared a complete set of specifications entitled "Airplane Receiving Equipment for Visual Radio Range-Beacons," which is available gratis to operators of airplanes or anyone interested, upon request addressed to the bureau. This includes information on receiving sets, reed indicators, pointer type indicators, combined course and volume indicating instruments, and an installation wiring diagram.

General information on the visual radio range-beacon system is given in Bureau of Standards Research Paper No. 159, "Development of the Visual Type Airway Radio Beacon System," obtainable from the Superintendent of Documents, Washington, D. C., for 20 cents. To secure satisfactory operation of any radio receiving equipment on most airplanes, it is necessary that the engine and all electrical equipment be carefully shielded and the airplane structure bonded. Detailed specifications for shielding and bonding are given in Appendixes 1 and 2 of "Second Report of Liaison Committee on Aeronautic Radio Research"; this publication is obtainable gratis upon request addressed to Aeronautics Branch, Department of Commerce, Washington, D. C.

Technical information on other phases of the airplane receiving equipment for the visual radio range-beacon system is given in the following publications, obtainable from the Superintendent of Documents, Washington, D. C., at the

prices stated: RP330, "Automatic Volume Control for Aircraft Radio Receivers," 10 cents; RP28, "Design of Tuned-Reed Course Indicators for Aircraft Radio Beacon," 5 cents; RP160, "A Tuned Reed Course Indicator for the 4 and 12-Course Aircraft Radio Range," 15 cents; RP338, "Theory of Design and Calibration of Vibrating-Reed Indicators for Radio Range Beacons," 10 cents; RP336, "A Course Indicator of Pointer Type for the Visual Radio-Range Beacon System," 15 cents.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, APRIL 20, 1932.

The stated monthly meeting of the Institute was called to order by the President, Mr. Nathan Hayward, at eight-fifteen p.m.

The President called upon the Secretary for the business of the evening. The latter reported that there was no business requiring consideration at this time.

The minutes of the March meeting were published in full in the JOURNAL of the Institute and were approved as published.

The President then introduced as the speaker of the evening Dr. W. F. G. Swann, Director, Bartol Research Laboratories of The Franklin Institute, who made his annual report on the work of the Bartol Research Foundation.

Dr. Swann emphasized particularly the great amount of work done at the Laboratories during the past year on the subject of cosmic radiations. His report was thoroughly illustrated by a number of striking experiments, showing the character of the researches which have been carried on. He referred especially also to the highly important and ingenious work which has been done in the discovery of isotopes of various substances at the Laboratory.

The reading of the report was followed by a brisk discussion, after which the meeting was adjourned at nine-forty-one p.m. The report was apparently thoroughly enjoyed by a generous audience.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, April 13, 1932.)

HALL OF THE COMMITTEE,
PHILADELPHIA, APRIL 13, 1932.

MR. EDWARD L. CLARK, *in the Chair.*

The following report was presented for final action:

No. 2940: Development of Method of Symmetrical Coördinates, Mr. Walter C. Wagner, Acting Chairman.

This report recommended the award of the Elliott Cresson Medal to Doctor Charles Le Geyt Fortescue, of Pittsburgh, Pennsylvania, "In consideration of his development of a method of symmetrical coördinates applied to the solution of polyphase networks, a development that marked a distinct advance in electrical engineering and is of great value in its practical application."

The following reports were presented for first reading:

No. 2936: Ballast Cleaner.

No. 2940: Liquid Purification Process.

No. 2945: Autogiro.

GEO. A. HOADLEY,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 20, 1932.)

RESIDENT MEMBERSHIP.

MR. FRANK L. O'BRIEN, JR., Machinery Dealer, 113 North Third Street, Philadelphia, Pa.

MR. EDWIN M. WOODS, Civil Engineer, Standard Oil Company of Pennsylvania, Philadelphia, Pa. For mailing: 415 South Forty-second Street, Philadelphia, Pa.

NON-RESIDENT MEMBERSHIP.

MR. FRANK A. JOHNSON, Electro-Plating, Miami Plating Works, 1132 N.E. Second Avenue, Miami, Florida.

CHANGES OF ADDRESS.

MR. WALTER ATLEE, 829 North Charles Street, Baltimore, Maryland.

DR. RAYMOND F. BACON, 500 Fifth Avenue, New York City.

MR. RAYMOND B. COOKSON, Chief Engineer, Brevoort Co., Inc., 720 Land Title Building, Philadelphia, Pa.

MR. WILLIAM G. ELLIS, 1473 Broad Street Station Building, Philadelphia, Pa.

MR. POWELL EVANS, 155 Rose Lane, Haverford, Pa.

MR. H. F. FLYNN, 205 Mill Road, Brookline, Delaware County, Pa.

MR. ERLE G. HILL, Mellon Institute of Industrial Research, Thackeray Avenue and O'Hara Street, Pittsburgh, Pa.

MR. DANIEL O. LANDIS, United States Naval Observatory, Washington, D. C.

MR. PERCY S. LYON, 3416 Warden Drive, Philadelphia, Pa.

MR. EUGENE MERZ, Florham Park, N. J.

MR. ARTHUR F. POOLE, Care Morse Chain Company, 305 Parkway, Ithaca, New York.

MR. FRANCIS R. WADLEIGH, 815 Eighteenth Street, N.W., Washington, D. C.

MR. WALTER C. WAGNER, Philadelphia Electric Company, 2301 Market Street, Philadelphia, Pa.

NECROLOGY.

Mr. B. A. Behrend, Wellesley Hills, Mass.
Mr. S. M. Curwen, Haverford, Pa.
General G. A. Ferrie, Paris, France.
Mr. R. B. Haines, Jr., Germantown, Pa.
Rev. Roland Ringwalt, Camden, N. J.

LIBRARY NOTES.

RECENT ADDITIONS.

ABBOTT, ARTHUR L. National Electrical Code Handbook. First edition. 1932.
APPLETON, E. V. Thermionic Vacuum Tubes and their Applications. 1932.
ARCHIBALD, E. H. The Preparation of Pure Inorganic Substances. 1932.

BERLINER, ARNOLD, AND KARL SCHEEL, Editors. Physikalisches Handwörterbuch. Zweite Auflage. 1932.

BRADFORD, DUNCAN. The Wonders of the Heavens, Being a Popular View of Astronomy, Including a Full Illustration of the Mechanism of the Heavens. 1845.

BRITTON, HUBERT T. S. Hydrogen Ions: Their Determination and Importance in Pure and Industrial Chemistry. Second edition. 1932.

CALEY, EARLE RADCLIFFE. Analytical Factors and their Logarithms. 1932.

CAVEN, R. M., AND G. D. LANDER. Systematic Inorganic Chemistry from the Standpoint of the Periodic Law. 1930.

Chemical Society. Annual Reports on the Progress of Chemistry for 1931. Volume XXVIII. 1932.

COPERNICUS, NIKOLAUS. Nicolai Copernici Thorunensis De Revolutionibus Orbium Caelestium Libri VI. Ex auctoris autographo recudi curavit Societas Copernicana Thorunensis. Accedit Georgii Ioachimi Rhetici de libris revolutionum narratio prima. 1873.

DEBYE, P., Editor. The Interference of Electrons. Authorized translation by Winifred M. Deans. 1931.

DELLER, ANTHONY WILLIAM. Principles of Patent Law for the Chemical and Metallurgical Industries. 1932.

Electrochemical Society. Transactions, 1931. Volume 60. 1932.

ELLIOTT, BEN. G., AND EARL L. CONSOLIVER. The Gasoline Automobile. Fourth edition. 1932.

ELLIS, DAVID. Sulphur Bacteria. A Monograph. 1932.

EVANS, ULICK R. The Corrosion of Metals. Second edition. 1926.

FRASER, RONALD G. J. Molecular Rays. 1931.

GAMOW, G. Constitution of Atomic Nuclei and Radioactivity. 1931.

GWIAZDOWSKI, ALEXANDER P., AND CHESTER B. LORD. Economics of Tool Engineering: Jig and Fixture Design. First edition. 1932.

HARDEN, ARTHUR. Alcoholic Fermentation. Fourth edition. 1932.

HEISENBERG, WERNER. The Physical Principles of the Quantum Theory. Translated by Carl Eckart and Frank C. Hoyt. 1930.

HUBERT, E. H. Manual of Electric Arc Welding. First edition. 1932.

Index Generalis. Annuaire Général des Universités, Grandes Écoles, Académies, Archives, Bibliothèques, Instituts Scientifiques, Jardins Botaniques et Zoologiques, Musées, Observatoires, Stés. Savantes. 1930–31.

International Conference on Bituminous Coal. Proceedings of Third Conference, 1931. Two volumes.

KEARTON, WILLIAM J. Steam Turbine Theory and Practice. Third edition. 1931.

KLEIN, G., Editor. Handbook der Pflanzenanalyse. Zweiter Band: Spezielle Analyse, Erster Teil. 1932.

LE BLANC, MAX, Editor. Ergebnisse der angewandten physikalischen Chemie. Erster Band. 1931.

LUCAS, A. Forensic Chemistry and Scientific Criminal Investigation. Second Edition. 1931.

MAXWELL, FRANCIS. Modern Milling of Sugar Cane. 1932.

METCALF, C. L., AND W. P. FLINT. Fundamentals of Insect Life. First edition. 1932.

MOSS, HERBERT. The Revised Heat Drop Tables (1931). H.P. 100 to 3200 lb./sq. in. Gauge; L.P. 14 to 19 lb./sq. in. Absolute. From the New Data and Formulæ of the late Professor H. L. Callendar. 1931.

MÜLLER, ERICH. A Laboratory Manual of Electrochemistry. Translated from the fourth edition by H. J. T. Ellingham. 1931.

NEEDHAM, JOSEPH. Chemical Embryology. Three volumes. 1931.

ORMSBY, H. France. A Regional and Economic Geography. No date.

O'ROURKE, CHARLES EDWARD. General Engineering Handbook. First edition. 1932.

OSBORN, CAMPBELL. Oil Economics. First edition. 1932.

OSTWALD, WILHELM. Colour Science. Authorised translation with an introduction and notes by J. Scott Taylor. Part I. Colour Theory and Standards of Colour. No date.

PENCE, WILLIAM D., AND MILO S. KETCHUM. Surveying Manual. Fifth edition. 1932.

POMEY, J. B. Cours d'Électricité Théorique. Tome III. 1931.

RABINOWITSCH, E. Grundbegriffe der Chemie. 1930.

REID, ELLIOTT G. Applied Wing Theory. First edition. 1932.

ROOT, RALPH E. Dynamics of Engine and Shaft. 1932.

Royal Society of London. Philosophical Transactions. Series A. Volume 230. 1932.

Science To-Day and To-Morrow. Compiled from a Series of Lectures Delivered at Morley College. 1932.

SEELY, FRED B. Advanced Mechanics of Materials. 1932.

Society of Chemical Industry. Reports of the Progress of Applied Chemistry. Volume XVI. 1931.

TREADWELL, F. P. Analytical Chemistry. Translated and revised by William T. Hall. Volume I. Qualitative Analysis. Eighth English edition. 1932.

U. S. Coast Guard. The Marion Expedition to Davis Strait and Baffin Bay under Direction of the United States Coast Guard, 1928. Scientific Results, Part 3: Arctic Ice with Especial Reference to its Distribution to the North Atlantic Ocean, by Edward H. Smith. 1931.

VAN BRUNT, G. A., AND A. C. ROE. Rewinding Data for Direct Current Armatures. First edition. 1932.

Wasserkraft Jahrbuch 1930–31. (5 Jahrgang.) 1931.

WATSON, WILBUR J. Bridge Architecture, Containing Two Hundred Illustrations of the Notable Bridges of the World. 1927.

BOOK REVIEWS.

FRANCE, A Regional and Economic Geography, by H. Ormsby, B.Sc. (Econ.), University of London, 515 pages, illustrations, plates, 22.3 x 14.5 cm. New York, E. P. Dutton and Company, Inc. Price $6.50.

There are some books that are a pleasure to read. When a book treats a subject seriously and is written with a style that gives delight, that book in my opinion both contributes to science and adds to literature. Miss Ormsby's geographic treatment of France is such a book. The earth has a way of being heavy. When a student in this field turns the land with a clean literary ploughshare a certain kind of intellectual fertility is bound to result.

After an introduction that treats with the French climate in its many moods and tenses Miss Ormsby describes the several geographical areas in turn. The Central Massif, inherited the Hercynian trends, was lifted up as a rugged block by the tertiary movements that raised the Alps. A wild and rugged country with the horizon marked by those vestigial volcanic plugs known as La Chaine des Puys, with Mont Dore and Cantal as the most conspicuous members. Thinly settled and of an elevation of four to five thousand feet one marvels at the effect that the Central Massif has had on the Gaul of the Roman and the France of the French.

By cut as much as by text Miss Ormsby supports her claims. Able drawings show how this central block has lifted great limestone areas on each flank to the south in Languedoc, to the west in Aquitaine, to the north in the Paris basin, to the east Rhone-Saône corridor. There is not space to follow the streams that lead into these several fertile areas or to observe how drainage and climate and soil all effect the character and activity of the populations.

The Armorican Massif, the Paris Basin, French Flanders, the Pyrenees, the French Alps, Alsace and Lorraine each has its separate story as derived from geography. Nor has there been neglect even of the small places such as Andorra, that tiny country in the Pyrenees, which carries political water on both shoulders. Corsica, an island miniature of the Central Massif, seems to be particularly tantalizing to the Napoleon-minded Frenchmen. The description of the Jura appealed to me most, partly because of its Karstic character with the rivers Loue and Doubs leaping full grown from subterannean caverns, and partly because it has been my great good fortune to have visited this unfrequented though picturesque part of France with its disappearing streams and its "vaux" and its "cluses."

The book ends with a careful survey of agriculture, industry and communications following which are appendices and a bibliography that testifies to a thorough familiarity with the literature. In addition to these prosaic necessities, there are such phrases as:

"There is a tendency throughout the Haute Planeze for pastoral industries to oust agriculture, however, and hay is now the most cherished crop; but La Basse Planeze still remains faithful to the plow,"

—or when speaking of the river Meuse, a frequent reference in dough-boy diaries:

"The river, meandering somewhat feebly over the flat-bottomed flood-plain some half to three quarters of a mile wide, appears to be a misfit in the garments of a more robustly developed ancestor."

Whether it is the description of the ways of the Aa or the trench of the Ill there is always the telling phrase, the new expression, the well chosen word that describes tersely the exact scene. It may be that literary expression has no place in describing pig-iron, hydro-electric power, the flax of the Vosges, or the many other details of geographic France. One can concede always a certain ferment for dealing with the wines of Bordeaux, Burgundy, Champagne and the Rhine. The happy expressions with which this informing book is written quite eclipse the few misprinted words and the "mauvais mauve" stain on the top edges of the book.

H. W. ELKINTON.

WASSERKRAFT-JAHRBUCH, 1930–1931, (5. JAHRGANG), HERAUSGEBER: Geheimer Baurat, Dr.-Ing. e.h. Dantscher, Ingenieur Carl Reindl, Munchen, 370 pages, illustrations, 23.5 x 15.5 cm. München, G. Hirtl, 1931. Price, bound, 22 marks.

After an interruption of two years the fifth issue of the Jahrbuch makes its appearance. It contains the usual interesting information on the water-power of continental Europe as well as articles on water-power application in Canada and Japan. The legal side of the question of the utilization of water-power and its evaluation are again considered in detail.

The third part is devoted to interesting discussions on large power plants and details in their management. Part IV is devoted to three papers on water power machinery, including Pelton wheels, turbines and turbine tests. In this volume is included a general index covering the earlier issues of the Jahrbuch, 1824 to 1931, volumes one to five.

The work is excellently printed, contains the necessary maps and illustrations, and is durably bound.

R.

THE QUEEN OF THE SCIENCES, by E. T. Bell, Professor of Mathematics, California Institute of Technology. A Century of Progress Series, 138 pages, illustrations, 13 x 19.4 cm. Baltimore, The Williams & Wilkins Company, and Associates, in coöperation with the Century of Progress Exposition, 1931. Price $1.00.

This book is among the first of a long series designed to set forth in simple language the reshaping of man's knowledge and his physical world in modern times. The Series is the outcome of the efforts of a committee under the National Research Council concerned with placing the message of the Exposition in convenient form for easy assimilation.

The reviewer feels that Professor Bell in this book is sounding a pæan to the Art of Mathematics, unconsciously, perhaps, but none the less truly, rather than to the Science of Mathematics. Less than ever does mathematical evolution deal with the marshalling of facts and their practical significance and increasingly do the advances resolve themselves from creative genius and amazing manipulative dexterity. It is the esthetic rather than the practical features of mathematics with which the author concerns himself.

The customary disdain of mathematicians for the accomplishments of other sciences comes to the surface more than once. A quotation from the author himself throws much light on the character of his book. "It is the perennial youthfulness of mathematics itself which marks it off with a disconcerting immortality from the sciences," he writes, and later: "No man, I believe, no matter how practical, could point to a more conspicuous example than matrices of the apparently futile things over which mathematicians labor as few others ever dream of laboring. And it would be difficult to find a better instance of the historical fact that the significant advances of mathematics and not a few of those of science are inspired by the spirit of pure mathematics. . . . After such an instance as this, scientists, educators, and others may be more willing to let mathematics develop according to its own nature, instead of insisting, as they have sometimes done, that it should draw its life from finance, bridge building,

statistics, or whatever happens to be popular at the moment in physics. . . . The deliberate effort to follow immediate utility in mathematics almost invariably leads to second or third rate work, and more often than not the very utility which is narrowly sought turns out to be not so great after all. . . . Mathematicians may safely be left to follow their own bent as their contribution to this age of science."

Those chapters are best in which mathematics is given freest rein to tell its own story. Mathematics being a language in itself is scarcely improved by too much translation. A very great deal that is said of mathematics alone in this book is none the less true of any other science or art worthy of professional standing. It seems to the reviewer that it should never again be necessary to "sell" mathematics after the work of Jeans, Einstein, Compton and a score of others, and he wonders if a public reaction will not soon set in against that amazing flood of good, indifferent and bad publications which currently is attempting to explain all things to all men at so much per volume.

It seems regretable that the author has chosen to ignore the significance and value of mathematics by only a few scattering references to the many advances in other fields heavily indebted thereto. The remarkable fruitfulness of the work of J. Willard Gibbs is a case in point, yet Gibbs is nowhere mentioned. The advances in statistics, thermodynamics and electricity are others—a most fascinating story. Professor Bell has written, however, in a thoughtful and provocative manner and there is sure to be something for everybody who has completed the high school standard of mathematics.

LESLIE R. BACON.

NEW VIEWS OF SPACE, MATTER AND TIME. By J. D. Ross, Superintendent and Chief Engineer of the Seattle Municipal Light and Power System. Fellow American Institute of Electrical Engineers, American Chemical Society. xxii–393 pages, diagrams, illustrations, 16 x 23 cms., cloth. Seattle, New Scientific Book Publishing Co., 1931. Price $6.50.

It has been said, "If you can measure that of which you speak and express it by a number you know something of your subject; if you cannot measure it your knowledge is meager and unsatisfactory." In the present work Mr. Ross supplements the work of others with his own experiments and is thus able to assign significant values to the smallest unit of which we know, as well as to compute the dimensions of space. He takes care to impress upon the reader a very few of the values most important to the physical theory he supports and, although the mathematical work is of the very simplest type possible, it is always included where necessary.

Starting with examples of the most familiar displacement phenomena, he leads us to a better understanding of electricity, magnetism, light, heat, matter, and space. The author's theory of conduction makes space the building stone of all existence. By careful steps checked by clever experimental work he leads to the conclusion that space is atomic, its atom being electromagnetic in nature; and that it is under enormous pressure since it would require a force of at least 2.69×10^{17} pounds per square inch to hold together material of the density of platinum, and the calculated force with which two one gram masses of electrons repel each other when placed one centimeter apart would increase our estimate

to above 3.2×10^{17} pounds per square inch. Also, space and not matter is the container of all energy. There is but one law of motion, that due to pressure, and attraction, therefore, does not exist.

Mr. Ross has made the presentation of this material particularly interesting by including numerous examples of the application of physical theory. As an example, he explains how the basic idea behind Maxwell's electromagnetic theory of light led to the development of insulating transformers, and how the study of wave lengths led Röntgen to the discovery of X-rays and Millikan to the discovery of the cosmic ray which is almost 1000 times shorter than the average X-ray. Although the book does not attempt to compete with the fanciful newspaper scientists there are many suggestions as to the possibility of great benefits which may be derived from a knowledge of the foundations on which the superstructure of our present day physics is built.

As the preface suggests, the higher man has lifted the torch and the further we have peered back into the darkness, the deeper has become the mystery of being, and yet the study of phenomena which affect our senses is our only method of penetrating the mist. Whether the author's conclusions will replace the long accepted views of the scientific world or be discarded by students of the future is not nearly so important as the fact that he has succeeded in presenting data which makes his position definite and his ideas clear. The reader must conclude that Mr. Ross knows the subject on which he speaks.

DANIEL B. CURLL, JR.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 405, Application of Practical Hydrodynamics of Airship Design, by Ralph H. Upson and W. A. Klikoff, 20 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1931. Price fifteen cents.

The design of a large high-speed airship is primarily a structural problem, in which the most important stresses are those due, directly or indirectly, to aerodynamic forces on the surface of the hull. The force on any small element of the surface is most conveniently divided into two components, respectively tangent and normal to the surface. The tangent or skin-friction forces are so small per unit area that they are structurally almost negligible compared with the normal forces; yet their total integrated resultant is responsible for almost the entire drag of the hull, whereas the normal components of pressure are so nearly balanced over a good hull that their net resultant is practically zero. The interreaction of these very substantial forces is, of course, through the medium of stresses in the hull, and in combination with fin and inertia forces they are essential not only from a structural standpoint but also in the consideration of stability and control. The distribution of velocity and skin friction can also be indirectly determined from the normal force distribution. An accurate determination of the latter and its effects is therefore of the very first importance.

Examples of practical airship characteristics are employed throughout.

Report No. 406, Drop and Flight Tests on NY-2 Landing Gears Including Measurements of Vertical Velocities at Landing, by W. C. Peck and A. P. Beard, 15 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1931. Price fifteen cents.

This investigation was conducted at the request of the Bureau of Aeronautics, Navy Department, to obtain quantitative information on the effectiveness of three landing gears for the "NY-2" (Consolidated training) airplane. The investigation consisted of static, drop, and flight tests on landing gears of the oleo-rubber-disk and the Mercury rubber-cord types, and flight tests only on a landing gear of the conventional split-axle rubber-cord type.

The results show that the oleo gear is the most effective of the three landing gears in minimizing impact forces and in dissipating the energy taken. The flight results indicate that in pancake landings with a vertical velocity at contact of 8 feet per second the maximum accelerations experienced are approximately 3.2g, 4.9g, and 4.4g with the oleo, the Mercury, and the split-axle rubber-cord gears, respectively.

The results also show that, in the good landings, larger impact forces were experienced subsequent to contact (generally less than 2.8g) than experienced at contact (generally less than 2.0g).

The oleo landing gear permitted severe landings to be made without violent rebound; but the Mercury and the split-axle rubber-cord gears caused very violent and dangerous rebounds.

A comparison of the results of the drop tests, based upon equal heights of free drops, does not show the relative merits of the landing gears as realized in flight tests. However, a comparison made upon a basis of equal heights of total drop (free drop plus vertical movement of the load during the initial stroke of the landing gear) is indicative of them.

Report No. 407, The Characteristics of a Clark Y Wing Model Equipped with Several Forms of Low-Drag Fixed Slots, by Fred E. Weick and Carl J. Wenzinger, 9 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1932. Price ten cents.

This investigation was undertaken to develop a low-drag fixed slot for an airplane wing which would avoid the complications and maintenance difficulties of the present movable-type Handley Page slot. Tests were conducted on a series of fixed slots in an attempt to reduce the minimum drag coefficient without decreasing the maximum lift coefficient or the stalling angle of the slotted wing. The tests were made in the N.A.C.A. 5-foot vertical wind tunnel on a Clark Y basic section having a 10-inch chord.

The best combination of wing and fixed slot that was developed had a maximum lift coefficient of 1.751, which was 34.6 per cent. higher than that of the plain wing. The angle of attack for maximum lift was raised 9°, from 15° for the plain wing to 24° for the slotted wing. The minimum drag of the wing with fixed slot was increased 52.6 per cent. above that of the plain wing, or a value about 38.8 per cent. above that for a slotted wing with the movable slot closed. Fixed slots might also be used at the tips of the wings only, in which case the total drag of an average airplane would be increased very slightly, causing a loss in high speed of only 1 or 2 miles per hour.

Report No. 409, The Elimination of Fire Hazard due to Back Fires, by Theodore Theodorsen and Ira M. Freeman, 9 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1931. Price ten cents.

A critical study was made of the operation of a type of back-fire arrestor used to reduce the fire hazard in aircraft engines.

A flame arrestor consisting of a pack or plug of alternate flat and corrugated plates of thin metal was installed in the intake pipe of a gasoline engine; an auxiliary spark plug inserted in the intake manifold permitted the production of artificial back fires at will.

It was found possible to design a plug which prevented all back fires from reaching the carburetor.

Analysis of the heat-transfer phenomena in the arrestor shows that (*a*) the length-diameter ratio of the individual passages is of first importance in determining the effectiveness of the device, (*b*) that the plug need not be heavy, and (*c*) that the thermal conductivity of the material of which it is made is only of secondary influence.

Measurements of the pressure drop across the adopted model show that the increase of engine-pumping loss caused by the presence of the arrestor is quite negligible; the reduction in volumetric efficiency amounts to a few per cent.

Report No. 410, The Theory of Wind-Tunnel Wall Interference, by Theodore Theodorsen, 11 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1931. Price ten cents.

This paper outlines the development of a general theory for the calculation of the effect of the boundaries of the air stream on the flow past an airfoil. An analytical treatment of the conventional closed and open jet types of rectangular wind tunnels disclosed the possibility of devising three distinctly new types: Tunnels with horizontal boundaries only, with vertical boundaries only, and with a bottom boundary only. Formulas are developed for the tunnel wall interference in each case for an airfoil located at the center of the tunnel. The correction is given as a function of the width to height ratio of the tunnel. The formulas are exact for infinitely small airfoils only, but give good approximations for spans up to about three-quarters of the tunnel width.

The surprising result is obtained that the three last-mentioned nonconventional types of wind tunnels all are superior to the conventional open or closed tunnels as regards wall interference. It is, indeed, possible to design two distinct types of semiclosed wind tunnels having no wall interference; namely, a square tunnel with horizontal boundaries and no side walls, and a rectangular type of a width to height ratio of slightly less than 2 : 1 and equipped with vertical boundaries only.

The author goes on to show that instabilities in the flow may occur for the free jet and the open bottom type tunnels, imparing the predictability of the tunnel wall corrections. A tunnel with a jet free on three sides and restricted only by a lower horizontal boundary extending along the test section from the entrance to the exit cone, is finally recommended as the most promising choice. The correction for this type is from five to eight times smaller than that of the corresponding free jet type.

PUBLICATIONS RECEIVED.

Man and Microbes, by Stanhope Bayne-Jones, A Century of Progress Series, 128 pages, illustrations, plates, 13 × 19 cms. Baltimore, The Williams and Wilkins Company, 1932. Price $1.00.

La Photographie, par Maxime Hesse et Claude Amédee-Mannheim, 204 pages, illustrations, 11 × 17 cms. Paris, Armand Colin, 1932. Price 10 fr. 50.

Le Calcul des Differences Finnes et ses Applications, par Alfred Henry, traduit de L'Anglais par A Sallin, 211 pages, 25 × 16 cms. Paris, Librairie Scientifique Hermann et Cie. Price 50 frs.

Jobs for the College Graduate in Science, by Edward J. v. K. Menge, 175 pages, 14 × 21 cms. New York, The Bruce Publishing Company, 1932. Price $2.00.

Association Theory of Solution and Inadequacy of Dissociation Theory, by Jitendra Nath Rakshit, 297 pages, 12.5 × 19 cms. Calcutta, S. C. Auddy & Co., 1930.

U. S. Treasury Department, Coast Guard. The "Marion" Expedition to Davis Strait and Baffin Bay under the direction of the United States Coast Guard, 1828. Scientific Results, Part 1, The bathymetry and sediments of Davis Strait. Noble G. Ricketts, and Parker D. Trask. 81 pages, illustrations, plates, maps, 15 × 23 cms. Washington, Government Printing Office, 1932. Price, in paper, 50 cents.

National Advisory Committee for Aeronautics. Technical Notes, No. 406, The Use of Large Valve Overlap in Scavenging a Supercharged Spark-Ignition Engine using Fuel Injection, by Oscar W. Schey and Alfred W. Young, Langley Memorial Aeronautical Laboratory, 10 pages, illustrations, quarto. Washington, Committee, 1932. No. 410, Experiments on the Distribution of Fuel in Fuel Sprays, by Dana W. Lee, Langley Memorial Aeronautical Laboratory, 14 pages, tables, illustrations, quarto. Washington, Committee, 1932. No. 411, Rapid Chemical Test for the Identification of Chromium-Molybdenum Steel Aircraft Tubing, by John C. Redmond, Bureau of Standards, 3 pages, quarto, Washington, Committee, 1932, No. 412, The Aerodynamic Characteristics of Airfoils at Negative Angles of Attack, by Raymond F. Anderson, Langley Memorial Aeronautical Laboratory, 11 pages, tables, illustrations, quarto, Washington, Committee, 1932. No. 413, The Compressive Strength of Duralumin Columns of Equal Angle Section, by Eugene E. Lundquist, 12 pages, illustrations, quarto, Washington, Committee, 1932. No. 414, Considerations of Air Flow in Combustion Chambers of High-Speed Compression-Ignition Engines, by J. A. Spanogle and C. S. Moore, Langley Memorial Aeronautical Laboratory, 10 pages, illustrations, quarto. Washington, Committee, 1932.

CURRENT TOPICS.

The Anodic Treatment of Aluminum.—(*Plating-Polishing-Finishing*, Feb. 1932.) Aluminum and its alloys are especially desirable in the fabrication of machinery and apparatus where comparative lightness is desired. Against these attractive features is set the fact that the metal is relatively susceptible to corrosion especially by salt spray and dilute solutions of acids and alkalies. This so-called anode treatment of aluminum results in the formation of a dense deposit of aluminum oxide over the surface of the metal and the coating varies from three to five hundred-thousandths of an inch in thickness.

The details of the process are given by Edwin Joyce who states that the aluminum or aluminum alloy is immersed in a tank of chromic acid solution. While thus immersed an electric current is passed through the solution, the aluminum serving as the anode. As is well known, oxidation tends to occur at this point while at the other electrode, the cathode, hydrogen instead of oxygen is liberated and a reducing action occurs. The concentration of chromic acid may vary from 3 to 10 per cent. and the current density from 2 to 100 amperes per square foot depending upon the type of alloy and its complexity of form. The treatment consumes about 60 minutes.

T. K. C.

THE FRANKLIN INSTITUTE

OFFICERS FOR 1932

President	NATHAN HAYWARD
Vice-presidents	HENRY HOWSON C. C. TUTWILER WALTON FORSTALL W. CHATTIN WETHERILL
Secretary	HOWARD MCCLENAHAN
Assistant Secretary and Librarian	ALFRED RIGLING
Treasurer	BENJAMIN FRANKLIN
Assistant Treasurer	MARSHALL S. MORGAN
Controller	WILLIAM F. JACKSON, JR.

Board of Managers

HENRY BUTLER ALLEN
GEORGE H. BENZON, JR.
EDWARD G. BUDD
FRANCIS T. CHAMBERS
G. H. CLAMER
EDWARD L. CLARK
WALTON CLARK
CYRUS H K. CURTIS
CHARLES H. EWING
SAMUEL S. FELS
ARTHUR W. GOODSPEED
CLARENCE A. HALL
GEORGE A. HOADLEY
A. ATWATER KENT
L. H. KINNARD
ELISHA LEE
ROBERT W. LESLEY
HORACE P. LIVERSIDGE
MALCOLM LLOYD, JR.
CHARLES PENROSE
GEORGE WHARTON PEPPER
JAMES S. ROGERS
GEORGE D. ROSENGARTEN
HASELTINE SMITH